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GEOLOGY AND MINING OF PETROLEUM IN POLAND[1]

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ABSTRACT

Among various structural forms with which oil fields may be connected, those of diapiric structure, known in many oil-bearing areas in Roumania, in the Caucasus, and elsewhere, are the least favorable for prospective drilling. They are places of mere manifestations of crude oil at the surface. Oil deposits of commercial value are found generally on different forms of structure, and may occur in more deep-seated forms, adjacent to, or otherwise associated with, diapiric forms of more superficial nature.

Folds, as they occur commonly in the northwestern part of the Median zone of the Polish Carpathians, showing different stages of diapirism, are disposed *en échelon*, and areas intervening between such fan-like diverging folds might be favorable locations for exploration for deep-seated oil horizons in the lower part (Cretaceous) of the Flysch. This possible oil reserve has not been investigated.

The longevity of Polish oil deposits depends on the primary or secondary nature of the reservoirs (whether differentiated by original process of sedimentation, or degree of subsequent cementation), on the content of gas in the reservoirs, and on the intensity of reservoir pressure.

In the sub-Carpathian province, comprising the foreland depression filled with Miocene formations, only three gas fields are being exploited, and it was only in 1932 that the first test well for oil was located there; locations for two more wells have been selected on the basis of preliminary geophysical surveys.

The Marginal zone of the Carpathian petroliferous province, consisting of a complex of strata in many places repeatedly superimposed one upon another as thrust slices (*skiba* in Polish terminology), is not promising for test drilling, with the exception of that part that has been thrust bodily, by a deep-seated thrust plane, upon the sub-Carpathian Miocene formation. At present two test wells have been commenced with the object of searching for this deep possibility, outside of the few productive areas of this type already known in Boryslaw, Rypne, Majdan, and Bitkow.

In Poland there are no reserves of proved oil areas, but there exist widespread and reasonable possibilities for future discoveries. With steady progress in efficiency

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and technical perfection of exploitation methods in old fields, with the inauguration of oil mining, and with general policies in the industry improving, it will be possible to lengthen the producing life of oil fields.

DIAPIRISM AND ITS RELATION TO PRODUCTIVE OIL FIELDS

The conception of diapiric structure, that is, folds in which the core unconformably penetrates overlying beds, was introduced into petroleum geology by L. Mrazec.[1] His idea of the origin of oil accumulation in diapiric structure may be stated as follows. The principal characteristic is that folding proper continues during the entire period of deposition, in consequence of which the older beds undergo more severe folding than the younger beds; as secondary phenomena, thrust faults develop shear faults or other lateral displacements, resulting in imbricate structure. Differences in pressure during that process lead to migration of oil or gas from more intensively compressed strata (in Roumania, the Aquitanian saliferous formation or the *Cornu Schichten*) into reservoir rocks (Meotic and Dacian) at the flanks of the folds. This migration is effected principally by capillarity and diffusion, though there is some movement through fissures. In order that the influence of diapiric forms may be favorable to the accumulation of oil, it is required, according to Mrazec's reasoning, that reservoir rocks be brought into disconformable contact with lower source rocks of this oil. According to Mrazec, saline domes are only one of the extreme forms of diapiric structure, all derived from one common cause. He sought this cause in a subsiding foreland being thrust under a mountain front.

Karl Krejci[2] in defining diapiric folds admits that the length of the folding period is only a secondary factor. Furthermore, he differentiates diapiric phenomena and saline intrusions proper (*Aufbruch, Durchbruch*).[3] According to his idea, the pressure of overthrusting of a nappe acts directly on a saline formation contained in the substratum, and sediments resting on this mobile and plastic layer in the substratum participate in the movement of the overriding nappe solely through friction. In folds in the process of formation, the lateral and vertical (overburden) pres-

[1]L. Mrazec, "Ueber die Bildung der Rumänischen Petroleumlagerstätten," *Cong. International du Pétrole*, Troisième Session (Bucuresti, 1910), pp. 119-20. "Conférence sur la géologie des gisements roumains du pétrole," *ibid.*, Tome I.

L. Mrazec and W. Teisseyre, "Aperçu géologique sur la formation salifère et les gisements de sel de Roumanie," *Moniteur Pétrole Roumain* (1902).

[2]Karl Krejci, "Die Rumänischen Erdöllagerstätten," *Schriften a. d. Gebiete der Brennstoffgeologie*, Heft 1 (Stuttgart, 1929), pp. 21-23.

[3]*Op. cit.*, p. 13.

sures in higher levels spread along this mobile substratum as far as the apex of the fold, where the harder formations are bent at acute angles and pierce the roof formed of the softer layers. However, lateral pressure alone could not explain the upward intrusion of salt plugs from depths exceeding 1,000 meters. Krejci, also Kraus,[1] observed that many short diapiric folds and salt anticlines or domes with longitudinal axes plunging sharply on both sides, are in chessboard pattern,—*en échelon.*

According to Blummer,[2] well developed diapiric folds are to be pictured as common folds the cores of which have become compressed and squeezed,—a process that at a certain degree of lateral pressure occurs in the core of any fold. Such closely compressed folds are characteristic of areas that were subjected to intense pressure and, according to him, they are in contrast to broad open arches in areas of only gentle folding. Blummer's explanation, involving a contrast between true diapirism and the mechanism of folding, is not correct, if the definition of diapirism is extended to the deformation of rocks of very diversified plasticity, for example, in the Egyptian oil fields where, according to Hume[3] and Mrazec, in some Tertiary folds the cores are composed of granite.

For a long time the conception of diapirism has been resisted in French literature, although French geologists were well aware of the occurrence, in folds, of abnormal contacts between formations of different ages, for example, along the northern slope of the western Pyrenees, in Andalusia, in Algier, and Tunisia.[4] Not long ago it was attempted to introduce for phenomena of this kind a separate term,—*l'extrusion.*[5]

In Roumania, the cores of many diapiric folds and saline intrusions (Aufbrüche) belong to the same geologic sequence. The flanks of saline plugs and salt anticlines (Moreni, Baicoi), as well as some diapiric folds having an Oligocene core (Bustenari), are the sites of the most abundant oil deposits. Therefore, it was thought that diapiric forms are generally the places where the largest accumulations of crude oil may be expected.

[1]M. Kraus, "Verticaldruck-Tektonik und Oellagerstätten," *Petroleum* (1923), p. 147.

[2]E. Blummer, *Die Erdöllagerstätten* (Stuttgart, 1922), p. 373.

[3]W. F. Hume, *Report on the Oilfields Region of Egypt* (Cairo, 1916), pp. 59-61.

[4]M. Dalloni, "La géologie du pétrole et la recherche des gisements pétrolifères en Algérie," *Université d'Alger* (1922), pp. 269-84.

[5]P. Viennot, "Première contribution à la connaissance des extrusions pyrenéennes," *Serv. de la Carte Geol. de la France Bull. 171* (1928), p. 49; "Die Erdölsuche im Pyrenäengelände," *Petroleum* (1930), pp. 646-47.

The cause for this was believed to lie in the larger difference in pressure in the central part of the fold, as compared with that on its flanks. The central part was believed to be the source of the oil, and the rocks on the flanks were thought to be only reservoirs. Geologists began to look for diapiric forms in every large sequence of sediments, and occurences of any distinct diapirism were recommended as most favorable locations for oil prospecting.[1]

In order, therefore, to avoid misunderstandings, it is necessary to define accurately what is understood under the term diapirism, and, to conform to the intention of the author of this term, the definition should be limited to folds in which a core of older formations pierces through a mantle of younger beds (piercement folds). If the pressure has not reached the necessary degree of intensity, such forms may grade, in the same tectonic structure, into forms showing only different dips in their upper and lower beds respectively. Independently of the intensity of pressure and probably through regional conditions of the surrounding area, and through lithologic peculiarities of the beds, there may develop, simultaneously with diapiric forms, and within the same areas, also shears and slips which, dependent on the inclination of the fold, may grade into overthrusts. The principal outward characteristics of diapirism are the very steep dip of the beds in the central part of the fold and slightly asymmetric structure, and in many places the variable direction of the recumbency of the fold. The steepness of the dips in the core of the fold, and absence of any distinct direction for the predominating inclination, differentiate diapiric structure from that of an ordinary asymmetrical fold, and cause as the next stage of development, shears and overthrusts. The diapiric structure is therefore an individual form of structure, independent of the dip of formations, but dependent on movements, principally in the upward direction.

In descriptions of Roumanian deposits there are references[2] to narrow cumulate (?) folds, *Stauantikline*, which generally accompany saline extrusions and are divided from the latter by synclines of variable width, many of them distinctly isoclinal in structure. These folds are either diapiric or normal in structure, but intensely compressed, that is, anti-

[1]I. Gubkine, *Mém. du Com. Géol.*, Nouv. Sér., Livr. 115 (Petrograd, 1915).
M. Dalloni, "Sur la géologie comparée des zones pétrolifères de l'Apennin et de l'Atlas," *Bull. della Soc. Geol. Italiana*, Vol. 42 (1923), p. 328.
W. F. Hume, *op. cit.*
I. P. Voitesti, "Quelques nouvelles données sur la genèse du pétrole des régions Carpatiques Roumaines," *Rivista Muzealui Geol.-Min. al Univ. din Cluj*, Vol. 4 (1930).

[2]Karl Krejci, *op. cit.*

clines at the stage of incipient diapirism. Other stages of diapirism may be expressed in the degree to which the upper beds have been displaced in relation to the core, or in the degree of deformation, that is, the amount of thickening or thinning of beds in the flanks and in the core respectively. This peculiar form of diapiric structure is the result, according to Mrazec, also Macovei,[1] of a new orogenic phase of a differentiation of the structure caused by the previous phase; however, diapirism could also quite readily occur during only one phase of orogenesis, as a result of essential lithologic differences between the lower and the upper beds within a concordant series of beds, and it is even possible for the upper beds to have steeper dips and more intense displacements than the lower beds.[2]

Diapiric structure is the result of folding processes; extrusions of salt are mostly the result of gravitational pressure on areas of more gentle folding.

Every form of geological structure is only an expression of a slow deformation in all three dimensions of rock masses (in the sense of bodies having three dimensions) in consequence of disturbance of their equilibrium. Such deformation is most simply expressed in a displacement of a part of the mass from a place of greater pressure in the direction of less pressure. The character of the backland and the foreland of a rock mass and that of its substratum introduce differentiation into the ultimate form of the mass, so that its distortion depends on the intensity of the surrounding influences. Diapirism constitutes one of such forms of special distortion; the nappes and slices (imbricate structure, *skiby* in Polish terminology) must also be considered as special developments differing from diapirism in that in diapirs vertical movement predominates, and in imbricate structure sideways and even horizontal movement predominates. Forms such as overthrusts and slices are the expression of a rather intense shortening of the upper surface of the mass, whereas diapiric forms are classed among deformations in which no important shortening of the surface strata has occurred relative to deeper horizons. All of those forms belong to undulations of a small radius, for

[1]S. Macovei, "La formation des gisements de pétrole en Roumanie," *Traveaux du Prem. Cong. International de Forages* (Bucuresti, 1925).

[2]Cross sections are found on the Potok fold (Poland), and also in the Paleozoic and Cretaceous formations of the Turner Valley (Alberta, Canada) fields. Compare the cross sections shown in Figure 12 of this article with the section of the Turner Valley field in Figure 14 of the article by Sidney Powers, "Occurrence of Petroleum in North America," *Amer. Inst. Min. Met. Eng. Tech. Pub. 377* (1931).

example the zone of diapiric folds surrounding the basin of Transylvania, where gentle folds of large radius[1] predominate.

DIAPIRIC STRUCTURE IN RELATION TO ACCUMULATION OF PETROLEUM

Roumania.—Karl Krejci[2] recently emphasized the fact that accumulations of oil in Roumania are found in relatively simple and widely arched (*weitgespannt*) forms of structure, and that complicated and compressed forms are of secondary importance as oil fields. According to him, gas fields are there located principally on straight anticlines such as Boldesti and Aricesti; also, the oil field, Filipesci, is on a straight anticline. Slight diapirism is shown in the productive dome of Runcu. The fields of Arbanasi, Ceptura, Pacureti, and Doicesci show intensified diapirism in the order indicated. Their volumes of production decrease in the order: Ceptura, Arbanasi, Pacureti, Doicesci.

In reality, the cross sections of Roumanian deposits and their location[3] justify the assertion that diapirs proper, according to Mrazec's definition, are found in the oil fields of Bustenari, Campina, Gura Draganasei, Glodeni (Laculete), Foloresci, and other places. The Runcu deposit (Fig. 1) and its prolongation, Chichura, and the deposits of Ceptura and Doicesci (Fig. 2) have no diapiric form. Between Bustenari and Runcu, Glodeni and Doicesci, or Foloresci and Filipesci (Fig. 3), special tectonic relations prevail: diapiric forms and more gentle folds are situated to some degree *en échelon*. In Ceptura only a differ-

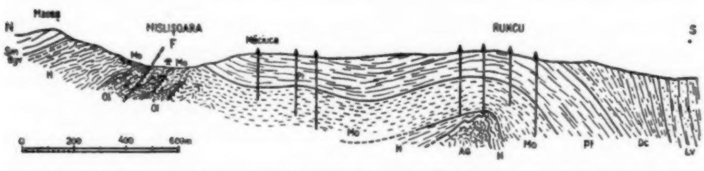

FIG. 1.—Cross section of oil fields Bustenari (Mislisoara) and Runcu. After H. Grozescu and D. Stefanescu. From S. Macovei, "Rumänien, Die Erdöl-Gas-und Asphaltlagerstätten," in Engler-Höfer, *Das Erdöl*, B. II, 2 (1930), Fig. 11. *Ol*, Oligocene. *A*, Aquitanian with salt. *H*, Helvetian. *Bgv*, Buglovian. *Sm*, Sarmatian. *Mo*, Mäotic. *Pt*, Pontian. *Dc*, Dacian. *Lv*, Levantin. Length of section, approximately 1.5 miles.

[1]L. Mrazec and E. Jekelius, "Aperçu sur la structure du bassin néogène de Transylvanie," *Guide des Excursions, deuxième Réunion Assoc. pour l'Avancement de la Géologie des Carpates* (Bucuresti, 1927).

[2]Karl Krejci, *op. cit.*, p. 76.

[3]S. Macovei, "Rumänien, Die Erdöl- Gas- und Asphaltlagerstätten," in Engler-Höfer, *Das Erdöl*, B. II, 2 (1930).

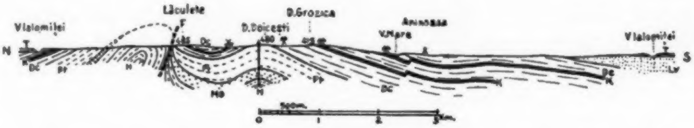

FIG. 2.—Cross section of Glodeni (Laculete) and Doicesci anticlines. After O. Protescu. From S. Macovei, "Rumänien, Die Erdöl-Gas-und Asphaltlagerstätten," in Engler-Höfer, *Das Erdöl*, B. II, 2 (1930), Fig. 31. *H*, Helvetian. *Mo*, Mäotic. *Pt*, Pontian. *Dc*, Dacian with lignite beds. *Lv*, Levantin. Length of section, approximately 6.7 miles.

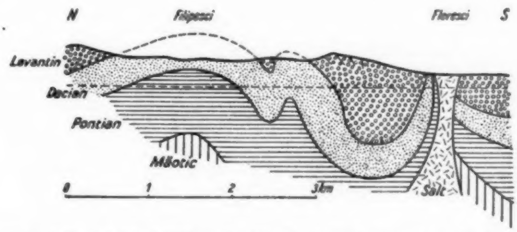

FIG. 3.—Anticlinal fold of Filipesci with diapir and extrusion of salt plug at Floresci. After Karl Krejci, "Die Rumänischen Erdöllagerstätten," *Schriften a. d. Gebiete der Brennstoffgeologie*, Heft 1 (Stuttgart, 1929), Fig. 29. Length of section, approximately 3.26 miles.

ence in the thickness between the Dacian and the Pontian beds is indicated, both in the northern and southern flanks of the fold,[1] and north of that highly productive fold is found an entire series of folds having true diapiric structure, such as Tatarul, Dobrota, Apostolache, and Salcia,—but all of them unproductive, as are also the saline extrusions (diapirs?) of Glodeni and Floresci, near the slightly productive folds of Doicesci and Filipesci.

In Roumania, truly diapiric forms in the zone of the Neogene are more numerous, the closer the Marginal zone of the Flysch is approached, although within the Marginal zone sliced and sheared masses and overthrusts[2] are more prominently developed.

Caucasus.—As regards the area of the Caucasus, even recently some geologists[3] have maintained that oil deposits of commercial value were

[1] Karl Krejci, *op. cit.*, p. 52.

[2] D. M. Preda, "Géologie de la valée du Teleajen," *Guide des Excursions* (Bucuresti, 1927), p. 167.

[3] I. Gubkin, *Mém. du Com. Géol.* (Petrograd, 1915), Nouv. Sér., Livr. 115; *Bull. du Com. Géol.* (1914), p. 441.

G. Strzetelski, "Étude analitique d'un pli diapyre et de l'influence de la tectonique sur l'accumulation du pétrole," *Prem. Cong. International de Forages* (Bucuresti, 1925).

located exclusively on folds of diapiric structure; however, the available facts permit us to state that on folds of that nature there are either no oil deposits at all (Taman peninsula), or if they exist (Atashka, Binagady), their production is small in comparison with that of fields on different structure.

Golubiatnikow furnishes a very plain and exhaustive description of the principal fold on the Apsheron peninsula:[1]

> Across the middle part of the peninsula, from Djarat on the north to the cape Zykh on the south, there is trending a large fold to which the most important oil fields of Balakhany-Sabunchy-Ramany and Surakhany are related. This fold is of a very complicated structure, its axis winding both in the horizontal and vertical planes; it forms a series of anticlinal uplifts plunging in general in the direction northwest to southeast. The intensive deformation of beds of various ages is markedly displayed along the general trend of these anticlinal uplifts. The beds of Oligocene are most severely deformed, being compressed and overturned in the core of the fold, standing nearly on their ends. The beds of Miocene follow next, of which the *Spirialis* beds are exposed on the flanks having a very high dip; the Pontian (Pliocene) beds are less deformed, similarly the productive series and the Akchaghil have gently inclined beds, while the Apsheronian stage is still less disturbed.

In the fields of the Balakhany-Sabunchy-Ramany area the beds of the productive series in the central zone of the folds have been subjected to greater pressure than on the flanks, particularly on the southern flank, and the contours of horizons I and V (Fig. 4) are not parallel but, conforming to the intensity of the folding, they either converge or diverge. In the first case, individual beds or even entire groups have become pinched out. In the central part and near the apex of the fold there are numerous faults, which, however, do not extend into the southern flank.[2] On the southern flank, productivity decreases toward the west as the dips of the beds increase. These are phenomena common to folds that have been formed at various stages of long periods of deposition, folds that are asymmetric, but not identified with either diapirism or *Stauantikline*[3] forms.

An example of a fold with relatively weak diapirism is the narrow and steep Atashka fold. Its relation to the productive Bibi-Ejbat dome

[1]D. Golubiatnikow, "The Detailed Geological Map of the Apsheron Peninsula," "Atashka Oil Region," *Mém. du Com. Géol.* (Leningrad, 1927), Nouv. Sér., Livr. 130, p. 299.

[2]N. Oucheikine, "Coupe géologique et tectonique de la série pétrolifère de la région de Balakhany-Sabunchy-Ramany," *Com. Géol. Matériaux, Livr. 1* (1916).

[3]Sharp complex folds formed against or near a resistant buttress.

FIG. 4.—Structure map of principal large fold, showing oil fields of Balakhany-Sabunchy-Ramany and Surakhany, Baku region. After N. Ushejkin, *Com. Géol.* (Petrograd, 1917). Contour interval, 10 feet. Solid contours on bottom of I horizon; broken contours on top of V horizon. Width of area shown, approximately 7.8 kilometers (4.9 miles).

(it is only the northwestern extremity of the larger elongate fold) is the same (Fig. 5) as that of near-by unproductive or poorly productive dia-

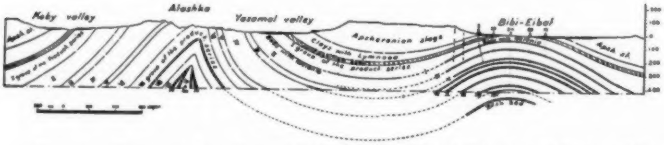

FIG. 5.—Cross section through Atashka and Bibi-Ejbat anticlines. After D. Golubiatnikow, "Atashka Oil Region," *Mem. du Com. Géol.* (Leningrad, 1927), Nouv. Sér., Livr. 130. *Pt*, Pontian. *Sp*, *Spirialis* beds. *Am*, *Amphisyle* beds (beds of Majkop, lower Miocene). Length of section, approximately 5.5 miles.

piric folds to the productive folds in Roumania. On the apex of a diapiric core, mud volcanoes are commonly found, as the Achtarma and Lok-Botan on the Puta fold, or the Bejuk-Dag on the Binagady fold; the muddy products penetrate lower Miocene clays (Majkop formation) in the core of the fold. As the Atashka fold is composed of beds grading upward from the lower group of the productive series, conditions are not conducive to productiveness. The mud volcanoes of the Caucasus are one of the phenomena that accompany diapiric folds.[1] On the apex of the extension of the Bibi-Ejbat dome, there have been tapped in the bay (and below sea-level) fissures filled with brecciated material, and a part of that apex is covered with eruptive material of this nature from a mud volcano. This material consists of Miocene formations and has been ejected from a depth of at least 1,600 meters through fissures in the productive series (Pliocene), the latter having a thickness in excess of 1,200 meters. However, Golubiatnikow does not deny that even underneath so regular a domal structure as exists in the area of the old Bibi-Ejbat fields, there might exist at great depth an incipient diapiric core, although the whole Bibi-Ejbat fold is neither a diapir nor a *Stauantikline;* the first fissures formed in the apex of the fold by the second tectonic movement in this area opened a way for a free exit of mud products.

The Binagady fold (Fig. 6) is composed of two parts:[2] (1) the principal southern part, composed of Miocene and Pliocene formations, and constituting the southern flank (the only flank that is still preserved) to-

[1] S. Kovalevsky, "Mud-Volcanoes of East-Transcaucasia," *Azerbejžanskoje Neftjanoje Choziajstwo* (Baku, 1928), p. 57.

[2] St. Zuber, "Die Erdöllagerungsverhältnisse in Binagady bei Baku, genetisch betrachtet," *Petroleum* (1929), No. 8, pp. 508-09. (The article contains a good digest of material contributed by Russian geologists; also the author's own observations.)

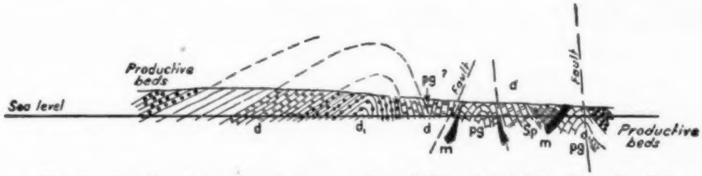

FIG. 6.—Southwest-northeast cross section of Binagady fold. After St. Zuber, *Geologic Explorations of Binagady* (Baku, 1924). *d*, Diatomaceous beds. d_1, Diatomaceous shales containing oil (Sarmatian). *sp*, *Spirialis* beds (Helvetian). *m*, beds of Majkop (lower Miocene). *pg*, Paleogene.

gether with the apex of a large and comparatively gentle fold, and (2) the northern part, pressed against the southern part along a fault surface and representing the shattered northern flank of the fold. This northern part displays in places distinct indications of a narrow secondary fold of the *Stauantikline* type, or of diapiric structure with products of mud volcanoes occurring in the Oligocene (Majkop clays). The gentle Binagady anticlinal main fold has developed gradually during the long period of deposition continuing till the end of the productive Pliocene; it was then partly eroded and again violently deformed into the most recent phase. In this last phase there occurred along its northern flank a shear fault, the formation of a secondary diapiric fold, and the eruption of mud material. The productive oil fields in the lower part of the productive series (Kirmaku beds) have been preserved only on the southeastern slope of the entire structure beyond the range of diapiric structure.

As regards the fields of Nowy Grozny, according to Kudrjavtzew:[1]

> the underground contour-lines have defined an elongated anticline extending in the direction from northwest to southeast, having two dome-shaped elevations. The cross sections through the wells on the northwestern dome, as well as on the southeastern one, display a sharp asymmetry on the field, different parts on the latter being inclined in opposite directions.

Similar features connected with an asymmetric fold were observed long ago, and attempts by some geologists (among them Strzetelski) to explain the location of the oil fields on the Grozny fold ostensibly by diapirism, can only mislead.

Poland.—In the Polish Carpathians the degree of folding is, on the whole, more intense than in the oil areas of the Caucasus, and the type of folding resembles that of the so-called Marginal Flysch zone (Randzone) in the Roumanian Carpathians.[2] The principal tectonic structural

[1] N. Kudrjavtzew, "Contribution to the Structure of the Novo-Grozny Oil Field," *Com. Géol. Matériaux*, Livr. 75 (1928).

[2] S. Macovei, *op. cit.*

features of the zone referred to, both in Roumania and in the Polish Carpathians, are the phenomena, developed to varying degrees, of shears, slices (*skiby*), and thrusts. In the Polish Carpathians they are localized principally in the wide Marginal zone along the sub-Carpathian depression and along the southwestern border of the Median group (Nowak's[1] "Median zone"). This Median zone displays the orographic features of a distinctly marked longitudinal depression, lying between the slightly more elevated Marginal zone on the northeast and a likewise elevated zone on the southwest (Magura zone) which latter passes into Czechoslovakian territory. The tectonic structure of the Median zone is different from that of the belts bordering it on the northeast and partly on the southwest. It is expressed in comparatively wide secondary longitudinal depressions that are synclinal in character near the surface, in places even isoclinal, and are divided by narrow secondary uplifts of anticlinal character: on these uplifts numerous oil fields are situated. On the contrary, the Marginal zone of the Polish Carpathians is composed of an entire series of packs of beds which are thrust one upon the other by sliding (*skiba*) along their surfaces and slanting upward, more or less, in the northeastern direction. In the Median zone structure of this type disappears: some complexa (packs) of beds, having monoclinal dips, extend from the Marginal zone northwest into the Median zone, and grade there into individual folds, which, however, are still strongly asymmetrical and are sheared off or disconnected to some extent. Folds of such structure are very common in the Median zone (Stróżna, Bóbrka-Równe-Rogi, Wulka-Rymanów, et cetera), but they also recur between the slices (*skiby*) in the Marginal zone (Schodnica-Urycz, Słoboda Rungurska). In other places the oil-bearing series in the Median zone forms more gentle and broad folds, especially close to the border of the southern zone, where some of them have been covered by overthrusts from the south (the oil fields of Harklowa and Męcina Weilka), and others lie just in front of the northern border of the southern zone, as the folds of Dominikowice-Libusza-Lipinki.

A type different from these asymmetric overturned folds is displayed in the Median zone by narrow folds, without any distinct uni-

[1] J. Nowak, "Le pétrole des Carpathes polonaises sous le point de vue de la géologie règionale," *Traveaux géograph. publiés sous la direction de E. Romer*, Livr. VI (Lwów, 1922); "Die Geologie der polnischen Oelfelder," *Schriften a. d. Geb. d. Brennstoff-geologie*, Heft 3 (Stuttgart, 1929).

American colleagues may also gain a general idea of Polish petroleum geology problems from the article by H. de Cizancourt, "Geology of Oil Fields of Polish Carpathian Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 1 (January, 1931), pp. 1-41.

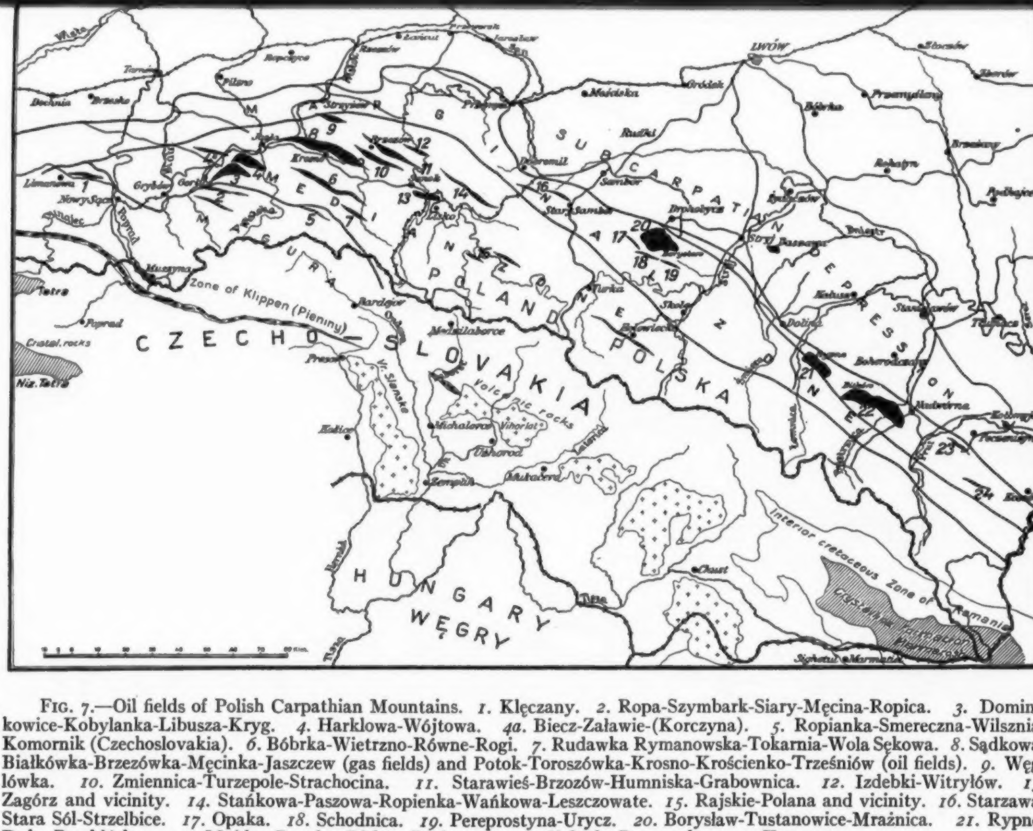

FIG. 7.—Oil fields of Polish Carpathian Mountains. *1.* Klęczany. *2.* Ropa-Szymbark-Siary-Męcina-Ropica. *3.* Dominikowice-Kobylanka-Libusza-Kryg. *4.* Harklowa-Wójtowa. *4a.* Biecz-Załawie-(Korczyna). *5.* Ropianka-Smereczna-Wilsznia-Komornik (Czechoslovakia). *6.* Bóbrka-Wietrzno-Równe-Rogi. *7.* Rudawka Rymanowska-Tokarnia-Wola Sękowa. *8.* Sądkowa-Białkówka-Brzezówka-Męcinka-Jaszczew (gas fields) and Potok-Toroszówka-Krosno-Krościenko-Trześniów (oil fields). *9.* Węglówka. *10.* Zmiennica-Turzepole-Strachocina. *11.* Starawieś-Brzozów-Humniska-Grabownica. *12.* Izdebki-Witryłów. *13.* Zagórz and vicinity. *14.* Stańkowa-Paszowa-Ropienka-Wańkowa-Leszczowate. *15.* Rajskie-Polana and vicinity. *16.* Starzawa-Stara Sól-Strzelbice. *17.* Opaka. *18.* Schodnica. *19.* Pereprostyna-Urycz. *20.* Borysław-Tustanowice-Mrażnica. *21.* Rypne-Duba-Perehińsko. *22.* Majdan-Rosulna-Bitków-Pasieczna. *23.* Słoboda Rungurska. *24.* Kosmacz.

Map shows three tectonic zones, each overthrust northeast toward sub-Carpathian depression (foreland): (1) Magura (not oil-bearing excepting in tectonic inliers), (2) Median (oil in Eocene-Oligocene), (3) Marginal (oil in Cretaceous-Oligocene). In sub-Carpathian depression gas is produced from Miocene. East-west length of area mapped, approximately 236 miles.

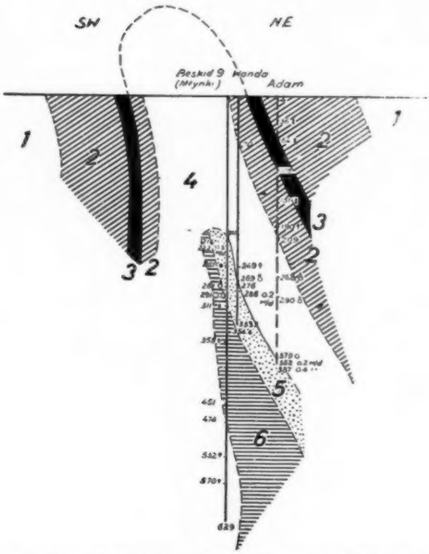

FIG. 8.—Cross section of Brzozów fold, Median zone, Polish Carpathian province. After J. J. Zieliński. *1*. Krosno beds (Oligocene). *2*. Menilite slates (lower Oligocene and upper Eocene). *3*. Hornstone beds. *4*. Red shales (Eocene). *5*. Ciężkowice sandstones. *6*. Cretaceous beds (same legend applies to Figures 9, 10, 11, 12).

lateral tilt, but showing on the contrary very diversified inclination of the axis in the direction of the general tilt, and with very steep dips in their cores. These are folds of a varying degree of diapirism, ranging from the *Stauantikline* types to true diapirs with piercing cores. A few cross sections at different places of the folds of Brzozów and Grabownica (Figs. 8, 9, 10) and of Potok (Figs. 11, 12), illustrate this type. Longitudinal and transverse faults, local pinchings-out of various beds, variations in the direction of the tilt, all these factors tend to complicate the structure in different places of the same fold.

In the mutual disposition of the individual folds, having diversified tectonic structure, it is observed that the asymmetrical folds of Dominikowice-Libusza-Lipinki and of Harklowa have at the north of them the narrow fold of Biecz, displaying various degrees of diapirism. The relatively wide anticlinal uplift of Weglówka lies between the northwest diverging steep diapiric folds of Potok-Trześniów and Blizna-Starawieś-Grabownica. Those two folds, jointly with a third that is squeezed

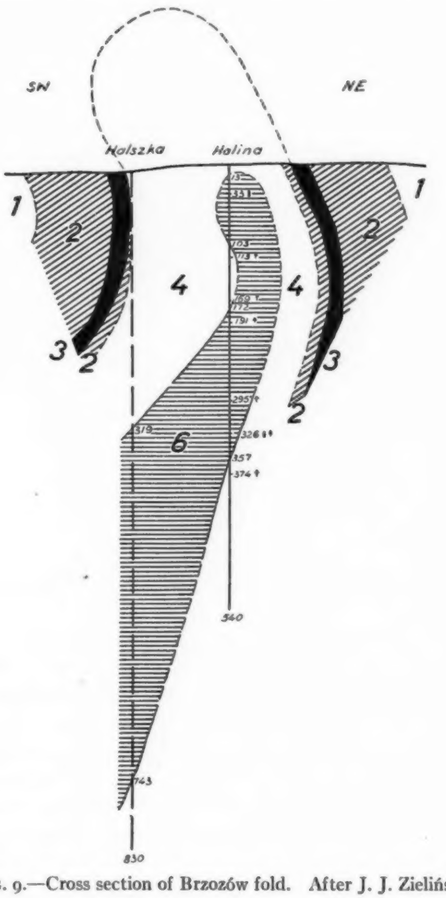

FIG. 9.—Cross section of Brzozów fold. After J. J. Zieliński.

between them, the diapiric fold of Zmiennica-Turzepole, furnish, through their location, an example of the *échelon* arrangement, perceptible even on maps of small scale.

The *échelon* disposition of the folds and their bifurcated or diverging fan-like form are the indications of weak and irregular tectonic pressure acting upon a mantle of sediments in the process of unimpeded deformation over some buried resistant mass, such as exists at each extrem-

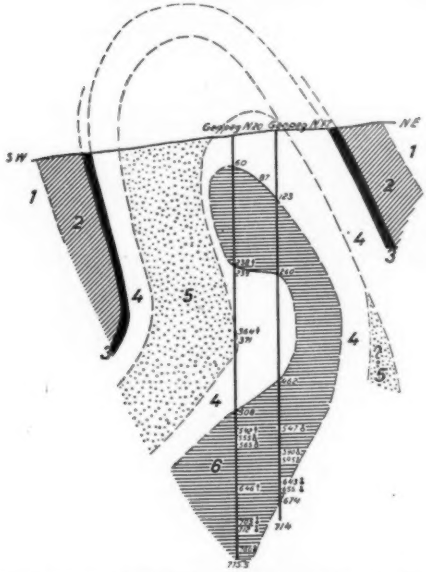

FIG. 10.—Cross section of Grabownica fold. After J. J. Zieliński.

ity of the Causasus or in the Neogene zone of Roumania. In the Polish Carpathians such allocation of folds can be only a deformation of a previous orogenic phase in the genesis of the general Carpathian structure, but preceding the final diastrophism. The zone of folds disposed *en échelon* within the Median zone of the Polish Carpathians lies southwest of the zone of large slices and overthrusts, which also involved the deeper formations including the Cretaceous. The principal oil areas in the Marginal zone, such as Borysław, Rypne, and Bitków, appear in the shape of deep-lying slices, entirely sheared off from their underground and overridden by other slices that are superimposed upon them. In the same zone, and northeast of the deep Bitków fold, is the diapiric upthrust of Starunia.

Cross sections of diapiric folds in the Polish Carpathians would not justify the supposition of their having been formed during two orogenic phases, were it not for their alignment which can not be reconciled with a single orogenetic phase. The *échelon* alignment could originate only in unconfined space, the underground of which would predispose

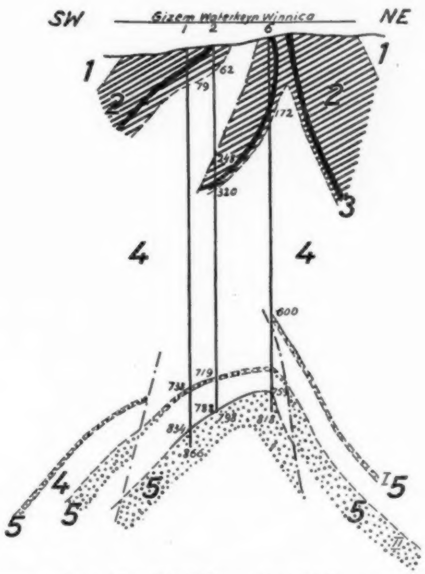

FIG. 11.—Cross section of Potok fold (near Winnica). After J. J. Zieliński.

the local character of sedimentation upon depressions and uplifts of the former surface (Nowak's "epi-synclinal" and "epi-anticlinal" sedimentation); this is proved by a differentiation of facies where the stratigraphic section is known.

The general law governing the accumulation of crude oil in reservoirs is solely a difference of pressure in a mass of rocks of various origins, in which the crude oil substance occurs, and the influence of either of the remaining factors, such as the structural form or the lithologic condition of beds, may, in any individual case, be either of primary or secondary importance. The structural "high" is the most readily recognized outward expression of differences of pressure within a complex of rocks, and it is just there that the practical importance of the structural "high" lies. However, general geologic experience shows that the location of diapiric structure of various degrees is commonly indicated merely by showings of hydrocarbons (oil, gas, asphalt). This can be substantiated in the Caucasus, in Roumania, and in the Polish Carpathians; also in France (Donzacq, Department of Landes; and Orthez, Department of Bas

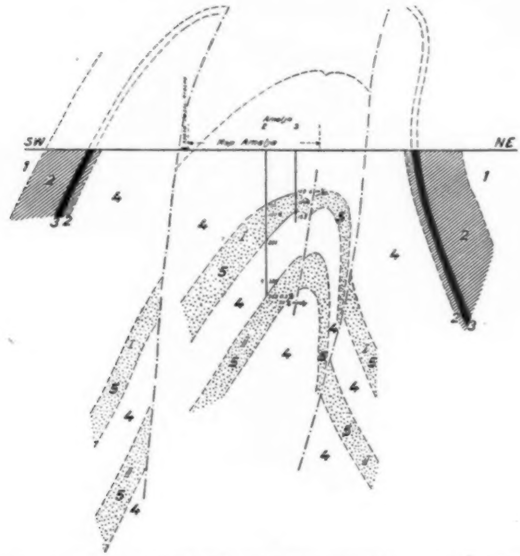

FIG. 12.—Cross section of Potok fold (near Toroszówka). After Ṫ. Obtułowicz.

Pyrenées), in Andalusia (Villamartin), in Algiers (Tliouanet), in Morocco, and in the Turner Valley, Alberta, Canada. It is possible that diapiric forms might be also the location of deposits of commercial value, and among such examples belong Bustenari, Campina, and Arbanasi in Roumania; less numerous are such occurrences in the Caucasus (Atashka); and in the Polish Carpathians oil fields are located in various parts of diapiric folds (Potok, Turzepole, Grabownica, Paszowa-Wańkowa) and were discovered long ago because of natural seepages. Diapiric forms might be among the causes of accumulation of oil, if in an exceptional case the genesis of this structure had been the only and first cause of differences in pressure within the mass; if, however, the difference in pressure had originated previously, that is, during the first deformation in the mass and prior to the development of the diapir structure on it, then the second deformation would lead to a new disturbance of a barely established equilibrium by the pinching-out of some of the beds and the thickening of others, by shears and faults, by a change of hydrodynamic conditions, and possibly also by the flushing-out of rocks which up to that time may have served as reservoirs. Even with the stratigraphic

columnar section accurately known, the diapiric form does not furnish any warranted indications regarding the location of oil or water horizons.

In areas of more gentle structure, such as those in Louisiana and in Texas, the Neogene zone in the Roumanian Carpathians, the Emba area north of the Caspian sea, and the region of Hannover in Germany, saline extrusions may be the cause of occurrence of oil deposits. Different, however, is the part played by diapiric forms, if they are the result of an orogenic phase in areas previously folded. Provided there exists a considerable difference in plasticity of overlying and underlying rocks (as in Irafi), folding within the period of only one phase may lead to structural forms having one character at the surface, and a different character at depth, and whose alignment in space resembles the relations between diapirs and more gentle folds in the Polish and in the Roumanian Carpathians, as well as in the Caucasus. In Iraq, the cover (shale, gypsum, and limestone of the Fars series) was sheared from its underground (Asmari limestones) at the time of folding, and was heaped into forms resembling in some places the *Stauantiklinen*, for example, the structure of Starunia in the Polish Carpathians. In other places, if there was no such shearing off, the movement of the deeper beds would be transmitted to the upper beds. This would not only happen through friction, while the upper beds remain perfectly passive, as is assumed by Krejci, but on the contrary, during deformation affecting both deeper and upper strata the deeper beds would pierce the upper beds. In this way structural forms develop that are now distinguishable outwardly from diapirs of a more complicated origin, such as some forms in Egypt (Gemsah). This may also result in surface structure entirely unconformable to the deeper zones.

In the area of the Polish Carpathians, the oil-bearing series was deposited in different places at various periods of the Cretaceous, Eocene, and Oligocene time. The oil-bearing zones are individual episodes of the facial development of sediments in accordance with the character of the shore lines or any uplifts of the underground. These sediments were formed during the long period of an insular regime in the Carpathian depression, with a slight folding of large radius slowly developing. Such chronic deformation of more or less extensive masses of rocks led to differences of pressure and caused an original emplacement of oil reservoirs and of impermeable rocks. It may be supposed that the first structural "highs," aligned *en échelon* and either rising or plunging in the direction of the strikes, have constituted the places of the first accumulation of crude oil in the sands of the Cretaceous, the Eocene (Ciężkowice sand-

stone), and the Oligocene (Borysław and Kliwa sandstones and Krosno beds). The flow of subsurface waters under a non-uniform load of overburden in the various parts of each mass, and subsequent cementation processes in the sediments, were the principal factors determining the original accumulations of fluids and gases, on a scale that was regional and probably comparatively large.

The area of the Median zone of the Polish Carpathian Flysch, prior to the pre-Tortonian (Middle Miocene) phase of orogenesis, might have resembled, both in alignment of folds and gentle structure, the Neogene zone at the margin of the Roumanian Flysch, southwest of the Valeni de Munte peninsula. Geologic development was completed with that phase. The principal orogenetic phase followed, that is, the Middle Miocene phase (pre-Tortonian), and the folds of the Median zone on a small radius, though retaining their mutual position, have undergone a new deformation, caused not only by pressure from the south, but also by resistance reacting from a buttress in the north. Large shears and slices formed in the entire Marginal zone, and here and there occurred displacements from the southwest of a type approaching a minor thrust sheet in importance. The rather gentle folds of the preceding phase were again deformed, some of them merely into overturned structure, that had been partly sheared from the substratum, and others assumed diapiric forms. The new structural forms, developing from foldings of small radius, may be different close to the surface from the forms at greater depth, because of slight shearing and also because of deformation nearer the surface, taking place to some extent in advance of deformation at greater depth. Nevertheless all those forms belong truly to the autochtone structure, not to the nappes.

Parts of former emplacements of oil accumulations that were left unchanged might now be preserved in the oil fields extending from Gorlice to Libusza, those of Harklowa and Węglówka, and some parts of the Bóbrka fold and of Schodnica-Urycz, all of which have undergone relatively less deformation at the final phase of orogenesis. Some of these oil fields (Harklowa) were protected as units from subsequent erosion, principally by having become covered from the south by overthrusts, and fields on the deeper element of the Marginal zone (Borysław, Rypne, and Bitków) have been similarly protected by a great series of slices superimposed on them. Most of the folds in the Median zone, from Bóbrka in the southwest to Paszowa-Wańkowa in the northeast, have developed into a prominently diapiric form, and such fields as are known today or as might still be discovered, are only deformed remnants of

formerly more extensive oil fields, remnants after entire groups of beds had become pinched out, disrupted by faults, and flooded by encroaching water under pressure,—all of this in proportion as deep structural forms became more abrupt toward the surface, and as the topography was more sharply carved out by erosion.

Synchronously with the deformation of former anticlines into diapiric or overturned forms, the wider synclinal depressions dividing them also underwent deformation, including a disruption of them, close to the surface, into small forms here and there isoclinal. Thus these depressions lost their importance as a possible source of bituminous material for the near-by structural "highs" undergoing further development. Longitudinal and transverse faults and displacements have disrupted the former structural "highs" into blocks, have shifted series of impermeable rocks, and have led in places to a complete flooding of former oil reservoirs.

The pre-Tortonian (Middle Miocene) phase of the Polish Carpathian orogenesis has introduced such differentiation of pressures into the former regional systems as could not be a factor favorable to the formation of oil reservoirs in the various stratigraphic series, but rather a factor generally negative and under best conditions only conservative.

The mechanism of the overthrusting and of the formation of slices (*skiba*) could only be a conserving factor for certain parts of the deposits, including their reservoirs and cap rocks. In some of those deposits, as Borysław, Rypne, Bitków, Harklowa, and in others of asymmetric structure, as Dominikowice-Lipinki, Węglówka, Schodnica, Słoboda Rungurska, accumulation of petroleum might have resulted not only from the original deformation of each of those masses, but also from the position of each of them in relation to larger transverse "highs" crossing the entire area of deposition. For deposits having a prominently asymmetric structure, as Bóbrka-Równe-Rogi, Wulka-Rymanów, Dominikowice-Lipinki, Węglówka, all in the Median zone, or Schodnica-Urycz, Słoboda Rungurska in the Marginal zone,—the final development of their forms could only be a more or less intense accentuation of structure which had originated earlier; therefore, it would constitute a factor beneficial to a certain degree.

In the diapiric forms, the final deformation was principally unfavorable to the accumulation of oil,—not uncommonly very unfavorable.

In prospecting work—in the Carpathians, as well as in other countries—possibly insufficient attention has been paid to the unfavorable features of diapiric forms, especially where they were the result of de-

formation of milder forms that had originated previously. The importance of some forms which are merely locations of oil showings, has been overestimated. Similarly, insufficient attention has been paid to the fact that many diapiric forms, in various stages of their evolution, are associated with adjoining more gentle forms of structure. In some places, especially where shearing has been developed, diapiric forms may remain somewhat more superficial structures than the deep forms with which they are associated and of the existence of which no indication is given by the structure of the folds directly overlying them, even though these folds be not of an overthrust type. Such deep-lying forms may contain oil reservoirs showing a higher degree of saturation and be beyond the injurous influence of artesian water, unlike the adjoining diapiric forms involving the same stratigraphic horizons.

In the Median zone of the Polish Carpathians, in the fields of Węglówka, Grabownica, and partly those of Potok, Cretaceous oil horizons have been found in formations differing facially from formations of the same age, as they are known farther west in the Polish Carpathians (west of the Nowy Sącz meridian) and also farther southwest, in Roumania.

These horizons might become the object of new prospecting in those parts of the region which have not become shattered by slices, as in the Marginal zone of the Polish Carpathians. Such promising areas are the folds found in the Median zone of those mountains, that enter *en échelon* between the steep diapirs and are covered at the surface by secondary disturbances. Such places can be selected by applying the general analytical principles of structural forms just discussed. On these premises the following areas may be pointed out as promising examples: the area between the diapiric fold of Potok and the northwestern extension of an analogous fold, that of Zmiennica-Turzepole. It is possible, also, that in the vicinity of Strachocina, and of its powerful gas reservoir, there may be discovered another deep-seated fold replacing the diapiric folds of Turzepole-Strachocina and of Krosno-Trześniów.

Oil horizons may lie in such forms at considerable depths and exploration will be expensive, but they may constitute just that reserve of oil deposits in the median part of the Polish Carpathians that should be searched for and found.

STATUS OF OIL MINING IN POLAND AND ITS POTENTIALITIES

The years 1894-1899 mark the period of the last expansion of the oil industry in Poland, when the new fields of Borysław, Rypne, and

Bitków were discovered. After the maximum production was reached in 1909 (207,000 cars),[1] it declined in the last few years of the World War from 85,000 to 82,000 cars annually, and even after the war there has been a steady decline since 1919 (Tables I and II).

TABLE I

POLISH OIL PRODUCTION BY DISTRICTS AND YEARS (1919-1931)
(Tank cars of 10,000 kilograms)

Year	*Mining District* *Drohobycz*	*Jasło*	*Stanisławów*	*Total*	*Percentage of World's Production*
1919	75,777	5,173	2,049	82,999	1.12
1920	69,058	4,932	2,492	76,482	0.83
1921	63,642	5,043	2,390	71,075	0.63
1922	63,032	5,604	2,670	71,306	0.57
1923	64,931	5,621	3,162	73,714	0.55
1924	67,317	5,711	4,089	77,117	0.57
1925	69,736	6,464	4,979	81,179	0.57
1926	67,884	7,033	4,666	79,583	0.56
1927	60,919	7,266	4,074	72,259	0.44
1928	62,393	7,619	4,279	74,291	0.40
1929	54,948	7,361	4,542	66,851	0.32
1930	52,895	8,535	4,847	66,276	0.34
1931 (est.)	48,950	9,712	4,711	63,373	

TABLE II

POLISH OIL PRODUCTION BY COMPANIES AND YEARS (1924-1931)
(Tank cars of 10,000 kilograms)

Companies	*1924*	*1925*	*1926*	*1927*	*1928*	*1929*	*1930*	*1931*
Premier-Małopolska	9,483	10,557	10,955	9,997	11,295	10,828	11,442	...
Karpaty-Dąbrowa	10,814	10,402	8,745	8,595	8,270	8,303	7,856	...
Fanto	6,375	7,720	7,728	6,545	5,939	5,513	4,544	...
Nafta	7,835	7,034	7,612	6,026	5,134	4,156	4,776	...
Total "Małopolska"	34,507	35,713	35,040	31,158	30,638	28,800	28,618	26,950
Limanowa (Silva Plana)	9,808	8,682	9,515	8,441	8,707	7,411	5,337	5,492
Galicja	6,622	8,930	6,868	5,630	7,556	6,314	5,799	5,275
Standard-Nobel	1,609	2,586	4,712	4,302	5,299	4,466	3,811	3,850
Rohag	2,502	2,100	2,575	1,838	1,972	1,989	1,855	2,087
Others	22,069	23,168	20,873	20,890	20,119	17,871	20,856	19,719
Totals	77,117	81,179	79,583	72,259	74,291	66,851	66,276	63,373

In 1926, in the fields of Borysław-Tustanowice, the average annual production per well was approximately 427 cars; in 1926, although the

[1]Tank cars holding 10,000 kilograms, 10 metric tons, or 3,200 gallons. In eastern Europe production is regularly stated in such cars ("cisterns").

fields had been extended through the Mrażnica area, the average productivity per well was 180 cars per annum; and in 1929 and 1930, only 100 and 96 cars, respectively. Table III illustrates the decline of production in these fields during the last three years, and the decline in Poland in general, although the drilling activity has not subsided, as is proved by more wells in the northwestern part of the Median zone of the Carpathian province (Jasło mining district) and in the fields in parts of the Marginal zone, but outside of Borysław (Tables IV and V).

TABLE III

NUMBER OF WELLS IN EXPLOITATION AND DAILY PRODUCTION PER WELL

Mining Districts Fields	*December, 1928 Number of Wells*	*December, 1928 Daily Production per Well (kg)*	*December, 1929 Number of Wells*	*December, 1929 Daily Production per Well (kg)*	*December, 1930 Number of Wells*	*December, 1930 Daily Production per Well (kg)*	*July, 1931 Number of Wells*	*July, 1931 Daily Production per Well (kg)*
Jasło	894	232	863	236	939	280	986	267
Drohobycz								
Borysław			163	1,831	170	1,698	159	1,675
Tustanowice			175	2,724	183	2,458	190	2,320
Mrażnica	103	5,290	108	4,157	101	4,536	106	3,634
Borysław, Tustanowice, Mrażnica	642	2,300	446	2,745	452	2,640	455	2,402
Fields outside of Borysław	850	257	878	244	939	260	968	272
Stanisławów	238	493	224	588	242	586	246	532
Total Poland	2,624	767	2,411	739	2,574	717	2,655	659

TABLE IV

NUMBER OF METERS DRILLED IN VARIOUS YEARS

Year	*Mining District Jasło*	*Mining District Drohobycz*	*Mining District Stanisławów*	*Total*
1920	16,239	39,995	2,979	59,213
1921	......	......	......	76,811
1922	......	......	......	89,250
1923	......	......	......	94,667
1924	20,436	46,360	34,507	101,301
1925	17,309	44,341	19,241	80,891
1926	20,185	52,832	14,067	87,084
1927	25,766	59,926	15,430	101,122
1928	28,558	58,558	13,067	100,101
1929	33,825	52,200	12,856	98,881
1930	38,551	58,867	19,180	116,598
1931	30,143	36,419	10,919	77,481

TABLE V

NUMBER OF WELLS COMPLETED IN RECENT YEARS*

District	*1926*	*1927*	*1928*	*1929*	*1930*	*1931*
Jasło		59	63	66	118	
Borysław-Tustanowice-Mrażnica		26	35	36	18	
Drohobycz district outside of Borysław		15	23	38	58	
Stanisławów		12	20	27	34	
Total	122	112	141	167	228	

*The total number of wells drilled to completion by January 1, 1931, is 5,595.

This general decline of the total volume of production is readily understood if it is realized that practically the same fields have been exploited during a long period of time (Table VI) and that those that are to-day still being extended or are being developed to deeper horizons, as Harklowa, Grabownica, and Rypne, are not classed among the most productive.

TABLE VI

LONGEVITY OF POLISH OIL FIELDS

Field	*Number of Years in Exploitation*	*Maximum Production Time (Year)*	*Maximum Production Volume (Cars)*	*Present Production Expressed in Per Cent of Maximum Production*
Bóbrka-Równe-Rogi	60	1903	4,753	23
Libusza-Lipinki	40	1894	2,520	41
Harklowa	55	Now	900	..
Potok-Krościenko	30	Now	1,700	..
Zmiennica-Turzepole	40	1904	350	67
Humniska-Grabownica	30	Now	1,126	..
Węglówka	40	1901	1,613	30
Ropienka	45	1895	696	34
Wańkowa	45	1919	1,744	76
Borysław	35	1909	192,000	22
Schodnica	40	1897	15,912	20
Urycz	35	1906	1,876	53
Rypne	36	1927	1,838	78
Bitków	30	1925	4,900	65
Słoboda Rungurska	50	1885	2,500	8

The post-war period, and particularly after 1925, when the first test wells in the Marginal zone had been disappointing, and when in the Median zone a number of such test wells had been abandoned, possibly prematurely, when attempts at extending some of the old fields, particularly Borysław and Bitków, fell short of substantial results,—that post-war period may be termed one of economy in field operations.

Attention was then directed to a more rational utilization of natural gas, to replacement of many steam engines by electric motors and Diesel engines. Reorganization of the fuel management produced tangible results as early as 1926, when in the Borysław field only 979 tank cars were used for fuel in field operations, as compared with 6,000 and 5,320 cars in 1921 and 1922, respectively. In 1929 and 1930 the respective quantities of crude oil utilized for fuel at the fields were: for the entire Drohobycz mining district only 295 and 100 cars, for Jasło district 48 and 24 cars, and for the Stanisławów district 57 and 48 cars, respectively. At the same time, production of casing-head gasoline increased at a gratifying rate (Table VII).

TABLE VII

PRODUCTION OF CASING-HEAD GASOLINE IN POLAND (1919-1931)

Year	*Cars*	*Year*	*Cars*	*Year*	*Cars*
1919	46	1923	208	1928	3,185
1920	59	1924	344	1929	3,450
1921	66	1925	979	1930	3,849
1922	92	1926	1,804	1931	4,084
		1927	2,774		

The Canadian (pole) system of drilling came into general use in Poland since 1887, and it was not until 1923 that two American subsidiaries, Standard-Nobel and Vacuum, began to introduce the cable (Pennsylvanian) system of drilling. The results obtained by this innovation were an acceleration by 100 per cent and more in the drilling of wells to depths of 1,500 meters, which by the old system required in the best operations as many as 32 months to drill; in 1929 the time required to drill wells of that depth in Mrażnica was reduced to 12 and for some wells to only 8 months. The cable system operated with a combination rig, fitted either for cable or for pole drilling, has come now into general use in Poland, with the exception of the shallow wells in the Jasło and Stanisławów districts, contributing thus very materially to a reduction of drilling costs. At present, drilling cost, including casing and overhead charges, in the Jasło district, with the maximum depth of wells 3,500 feet, are about $8.00 per foot; in the Stanisławów district, with wells nearly as deep, the cost is approximately $4.00, and in the Borysław area, with wells as deep as 5,000 feet, the cost ranges from $8.00 to $16.00 per foot. Labor and the cost of casing constitute usually about 50 per cent of the total drilling expenses.

Drilling by the rotary system has been repeatedly tried since 1923 by the Premier Company (Małopolska) in Borysław and in the vicinity of Bitków (Starunia), but without satisfactory results; of a more general use of this sytem in Poland, only investment costs now stand in the way. Investment in the rotary system is greater than in the cable system, for which the Polish factories already turn out the required standardized casing and tools.

During the last two years technical initiative has been directed principally toward rationalizing exploitation in fields where lease conditions permitted. After experiments with repressuring by air, in 1928 in the fields of Wánkowa and in 1929 in those of Rypne, none of which produced definite results because the natural conditions of the reservoir rocks were not considered, this system has been applied successfully in the fields of Schodnica; by forcing air into 2 wells, production of 40 surrounding wells has been stimulated from 9,400 to 11,255 kilograms per day. Repressuring by gas is being gradually introduced in Lipinki (Jasło mining district) and in Ratoczyn (Borysław). The Małopolska Company is introducing this method on its properties on the Potok fold, and is taking gas from its Sądkowa wells, which produce gas exclusively, and are located on the same fold. The Galicia Company is about to utilize the gas from its well in Strachocina to supplant pumping on this company's wells on the Grabownica fold. Thus the first steps are being taken toward convincing the oil industry of the necessity of maintaining production by improved engineering methods and of avoiding the waste of natural gas that has been practiced in the years of the largest oil production.

More than 77 per cent (2,282,000 cars) of the total volume of oil produced hitherto in Poland (2,965,000 cars) has been contributed by the fields of Borysław-Tustanowice-Mrażnica, and these fields still contribute, after producing for 30 years, as much as 66 per cent of the total production of Poland. The comparatively long life of the production of this deposit is caused by its principal oil horizon, the Borysław sandstone, having become disrupted into many distinct reservoirs of varying productivity, in consequence of lithologic peculiarities of this horizon, both primary (sedimentary) and secondary (cementary) in character. Another cause is the high content of natural gas in the deposit; the Borysław fields hold the first place in gas production (in 1929, 276,635,000 cubic meters; in 1930, 242,612,000 cubic meters; in 1931, 211,374,000 cubic meters) in spite of the existence in the Polish Carpathians (Męcinka-Sądkowa, Bitków) and in the sub-Carpathian zone (Daszawa near

Stryj) of fields producing gas exclusively. The total production of natural gas in Poland is shown in Table VIII; in 1930 the average flow per well was 0.33 cubic meter per minute. The fact deserves attention that among the Borysław-Tustanowice-Mrażnica fields those of Mrażnica contain the most gas, and in reservoirs farther down the dip than the oil reservoir. In Mrażnica, the average gas production per well in 1928 was 2,813 cubic meters per day; in 1929, 2,900 cubic meters; and in 1930, 2,417 cubic meters. For the entire Borysław-Tustanowice-Mrażnica area the corresponding figures were only 1,250, 1,290, and 1,127 cubic meters per day. At the end of 1931 a well drilled farthest south in Mrażnica (Pionier Company) produced 86,400 cubic meters per day.

TABLE VIII

PRODUCTION OF NATURAL GAS IN POLAND (CUBIC METERS)

		Mining District		
Year	*Drohobycz*	*Stanisławów*	*Jasło*	*Total*
1920				404,795,000
1921				400,126,000
1922				403,137,000
1923				390,058,000
1924				437,751,000
1925				535,011,000
1926	344,409,000	78,697,000	57,856,000	480,962,000
1927	331,744,000	76,858,000	45,537,000	454,139,000
1928	353,271,000	62,150,000	44,067,000	459,488,000
1929	375,142,000	43,007,000	49,138,000	467,287,000
1930	362,646,000	48,426,000	78,120,000	489,192,000
1931*	339,414,000	47,037,000	83,953,000	472,536,000

*1931 - estimated.

According to calculations by Tołwiński,[1] the productive area proper of Borysław measures 1,140 hectares (2,816.94 acres), and the average production per hectare (2,471 acres) approximates 1,939 cars, that is about 2 tons per square meter of surface from several horizons in the Oligocene (Borysław sandstone), and in the Eocene and Cretaceous (Jamna sandstone). The thicknesses of these horizons are variable, and it would be difficult to arrive at the true capacity of reservoir rocks, which, if they were 20 meters thick, would be 10 per cent, and if they were 10 meters thick, about 20 per cent. According to calculations made for some separate and more precisely defined fields,[2] the thickness of the

[1] K. Tołwiński, "Wydajność naftowych pól Borysławia, z mapą 1:25,000" (Productivity of Oil Fields of Borysław, with Map 1:25,000), *Karpacka Stacja Geologiczna Statystyka Naftowa Polski* (Borysław, 1931), No. 7.

[2] K. Bohdanowicz and S. Jaskólski, "A Contribution to the Study of Borysław Sandstone," *Polish Geol. Soc. Annals*, Vol. V (1928).

Borysław sandstone being 10 meters, productivity is 24 per cent, and the true porosity, as determined from drill cuttings, ranges from 10.5 to 15.38 per cent for the Borysław sandstone, and from 9.79 to 12.77 per cent for the Eocene sandstone. Such discrepancy between effective porosity and productiveness can be explained only by strong pressures prevailing in the deep Borysław reservoirs.

By keeping up the gas pressure in the various reservoirs, it is possible to lengthen the period of economic exploitation of the Borysław fields. Also other oil fields, like those of Bitków and Potok, and even fields as old as Równe-Rogi, still hold sufficient gas for that purpose. Even the oldest fields are not exhausted and some of them still display the presence of energetic gas, for example the extension of the Zmennica-Turzepole fold in Strachocina. The decline of production does not appear to be so threatening as it seems from the statistical figures quoted in Tables I and II. In 1930, according to Tołwiński,[1] from among 288 newly drilled wells there were 192 with a positive result, and 15.8 per cent were dry. In the Jasło district, 22 per cent were dry; in the Stanisławów district, 11.8 per cent; and in the Drohobycz district 7.9 per cent. A similar percentage of dry wells was obtained in Poland also in 1928 and 1929.

For individual wells in Borysław, whose productivity during the second year ranged from 86 to 93 per cent of that of the first, the time of life will exceed 10 years. With their productivity declining in the second year to 45 per cent, the wells reach their economic limit after 3 years. The average life of Borysław wells was approximately 6 years. In the Jasło district, with the economic limit ranging from 25 to 20 kilograms per day (14-11 gallons per day), the life of the wells is 20-30 years and longer. In Poland, the number of wells having a production in excess of the average ranges from 2 to 2.3 per cent of the total number of producing wells, and these wells contribute 50 per cent of the country's total production. Economy of exploitation and technical perfection may lower the economic limit of productivity in the Borysław fields, thus lengthening considerably the life of wells. One of the conditions preventing such reforms is the subdivision of tracts into small leases, a result of the old oil legislation, introduced after several unsuccessful experiments in 1884, on the basis of the right of accession, granting to the landowner rights to the subsurface and to useful deposits contained therein. At present we await a thorough reform of oil legislation that will rationalize prospecting and exploitation of deposits.

[1] K. Tołwiński, "Statystyka Naftowa Polski, 1930," No. 12 (1930).

If it is assumed that the term, petroliferous province, applies to areas constituting either a tectonic unit of the first order, or a group of units of minor rank, two such provinces may be distinguished within the boundaries of southern Poland: (1) the sub-Carpathian province, comprising a part of the foreland in front of the margin of the Carpathian folding and (2) the Carpathian province, comprising an entire complex of geologic units of diversified structure. The demarcation between those two provinces is conditional, and a part of the first, near the orogenic front of the Carpathians, may be classed in the Carpathian province.

In the sub-Carpathian province, until now only prolific gas fields have been discovered (Daszawa, Kałusz); test drilling, having for its object the investigation of the lower sequence of the Miocene, the upper series of which contains the gas horizons, has been commenced by the Pionier Company. By means of this company large companies and the Government coöperate in prospecting work.

The first test well was located near Rachiń, north of the town of Dolina and southeast of the Daszawa gas fields. It was decided to make two more locations (southeast of the Kałusz gas wells near Grabówka, and north of the town of Nadwórna), after this part of the sub-Carpathian depression had been investigated by the seismic and magnetic methods.

The Carpathian province contains oil fields (and oil and gas fields) in both of its natural structural zones (Median and Marginal), a general description of which is given in the first section of this paper. Prospecting wells within the limits of the Marginal zone had for their object the investigation of the deep tectonic element, that is the slice which has become known in Borysław, Rypne, Majdan, and Bitków. At present the Pionier Company is drilling one well on the slice (*skiba*) of Orów, southeast of Borysław, on a supposedly secondary uplift of this deep slice which plunges, beginning at Bitków, toward the northwest through Rypne and Borysław, under an entire series of shattered minor slices (*skiby*). Another well has been located by this company on the extension of the Słoboda Rungurska fold, which constitutes a secondary tectonic unit emerging in front of the Bitków slice.

The area of the Marginal zone in its more precise limits, between the slice of Skole and the edge of the sub-Carpathian depression, occupies approximately 240,900 hectares (930 square miles); the producing and the proved areas within it, not everywhere of economic value, comprise approximately 5,262 hectares (20.31 square miles), or 2.2 per cent of the total area.

The area of the Median zone, within very broad limits, occupies about 1,454,400 hectares (5,612 square miles), of which, from the town of Nowy Sącz on the northwest to Żabie on the southeast near the Bukowina frontier, there are approximately 6,120 hectares (23.62 square miles) of producing and proved lands, or approximately 0.42 per cent of the total area. Of the tremendous area of the Carpathian petroliferous province, 97.4 per cent has not been tested at all commercially. It may be expected, as has been explained in the first section, that a large part of this area, composed of complexes of slices (*skiby*), or of deeply folded formations in secondary longitudinal depressions of synclinal structure, is not promising for oil prospecting. However, within the area of the Median zone, between the meridians passing through the towns of Jasło and Sanok, there prevail geologic conditions justifying explorative drilling to deeper Cretaceous horizons on the steep folds of the diapiric type.

Thus there are no reserves of proved oil areas, but there are well founded possibilities of obtaining positive results in the sub-Carpathian, as well as in the Carpathian, province. Prospecting wells recently commenced are expected to yield more detailed information about the underground structure of Polish oil lands.

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OIL AND GAS POSSIBILITIES OF FRANCE[1]

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ABSTRACT

Nearly the entire oil production of France comes from Oligocene sand lenses in the Péchelbronn field in the Department of Bas-Rhin, Alsace, where it has been mined for many decades by means of shafts and galleries in addition to being recovered in recent years from wells. A total production of 12,210,000 barrels (1,720,209 metric tons) had been extracted from the field up to January 1, 1931. A relatively small amount of oil (19,038 metric tons or 141,600 barrels) has been extracted at Gabian, Department of Hérault, in southern France, where Triassic strata constitute the producing formation. A few barrels have been obtained by drilling in a graben in the Limagne (Auvergne) where large asphalt seepages are found surrounding volcanic necks in Oligocene sediments. Numerous asphalt seepages also exist in Triassic rocks throughout a belt paralleling the Pyrenees Mountains in the extreme southwest. Natural gas emerges from various Mesozoic and Tertiary strata in and near the southern extremity of the Jura Mountains, where the village of Ambérieu has been supplied with gas for years from several wells drilled near Vaux-en-Bugey (Vaux-Fevroux). Bitumen-impregnated sandstones of various ages are found in a belt along the east flank of the Jura. Although France contains several sedimentary basins in which possibilities of commercial oil exist, the tectonic conditions are in general complicated in the vicinity of the best indications. A vast amount of geologic work, and of geophysical work geologically directed, will be necessary in order to make discoveries, but new fields of commercial importance may ultimately be found.

INTRODUCTION

Although petroleum and natural gas indications have been known in France for centuries, this country has not been an important producer and discussions still take place as to whether it will ever be found to be commercially petroliferous. The object of the writer is to set forth what is known on the subject to serve as a background for any geologist who may wish to pursue the elusive petroleum possibilities further with the help of the references appended.

Oil was known at Gabian in the Department of Hérault in southern France as early as 1608, but the country first appeared in the schedules of petroleum production at the end of the World War. The Péchelbronn field in the Department of Bas-Rhin in Alsace had been producing for a long time both under French and German rules; but, owing to changes

[1]Read before the Association at the Oklahoma City meeting, March 26, 1932. Manuscript received, April 21, 1932.

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in ownership of this district, Table I does not furnish a full statement of French production.

TABLE I

OIL PRODUCTION OF FRANCE, 1918-1931*

Year	*Production† in Barrels*
1918	363,000
1919	334,000
1920	356,000
1921	389,000
1922	496,000
1923	403,000
1924	426,000
1925	459,000
1926	478,000
1927	525,000
1928	512,000
1929	520,000
1930	523,000
1931	517,000
Total	6,301,000

*From *La Revue Pétrolifère* (May 3, 1930).

†Production in previous years credited to Germany.

Perhaps the best comprehensive description of the oil possibilities of France is an article by Redfield (113)[1], on pages 97 to 103 of which the possible oil-bearing regions of the country are classified as (1) the Rhine trough, (2) Jura Mountains, (3) Lower Languedoc, (4) Aquitanian basin, (5) Paris basin, and (6) Limagne valley. Redfield's paper, like all literature on the subject, has been freely used by the present writer, who regrets that space and familiarity with French geologic literature do not enable him properly to give individual credit to all geologists and others who have contributed to knowledge of the subject. He wishes, however, to express appreciation of the helpful perusal and comment on the manuscript by W. P. Haynes and of suggestions by other geologists.

GENERAL STRATIGRAPHY OF FRANCE

Although stratigraphy is referred to under each of the petroliferous areas, a few preliminary remarks and a tabular view are pertinent as regards the geologic formations of the country as a whole. Not only is France endowed with rocks of all ages from very ancient to the most recent, but great variations exist in thicknesses in different regions.

[1]References to literature will be found at end of paper.

TABLE II

FRENCH CLASSIFICATION OF GEOLOGICAL FORMATIONS
(By W. P. Haynes, Frederick G. Clapp, and Pierre Lamare)

Era	System	Period		Stage	Sub-Stage or Facies	Equivalent division in older Classifications or in Germany			Oil indications
Cenozoic	Quaternary	Recent Pleistocene							
	Tertiary	Pliocene		Upper Pliocene	Villafranchien Calabrien	Silicien	Formerly Quaternary		
				Lower Pliocene	Astien Plaisancien			Neogene of Haug	
		Miocene		Pontian	Sahelien				
				Sarmatian					
				Vindobonian	Tortonien Helvetien				
				Burdigalian Aquitanian					
		Oligocene		Chattian Stampian Sannoisian	Firmitien Rupelien Lattorfien	Tongrien	Neo-Nummulitic of Haug	Nummulitic of Haug	Bitumen seepages & heavy oil in Rhine Valley & the Limagne
		Eocene		Ludian	(Bartonien)	Priabonien	Parisien Neo-Nummulitic of Haug		Some asphaltic impregnations in Sandstones in the Jura Mts.
				Bartonian	Bartonien Anversien				
				Lutetian					
				Londinian	Cuisien (or Ypresien) Sparnacien	Suessonien or Paleocene	Eo-Nummulitic of Haug		
				Thanetian Montian					
Mesozoic	Secondary	Cretaceous	Upper Cretaceous	Danian (?)			Neo-Cretaceous of Haug		
				Senonian	Maestrichtien Campanien Santonien Coniacien				
				Turonian	Angoumien or Provencien Ligérien or Salmurien		Meso-Cretaceous of Haug		
				Cenomanian					
			Lower Cretaceous	Albian	Vraconnien Albien				
				Aptian	Bédoulien Gargasien	Urgonien	Eo-Cretaceous of Haug	Neocomien	Bitumen
				Barremian					
				Hauterivian		Neocomien			Asphaltic impregnations in Sandstones in the Jura Mts. and bitumen at Ste. Suzanne in Aquitanian basin
				Valanginian	Valanginien Berriasien				
		Jurassic	Upper Jurassic	Portlandian			Upper Oolite of Haug	White Jura (Malm)	Asphaltic impregnations in Sandstones in the Jura Mts.
				Kimmeridgian			Middle Oolite of Haug		
				Lusitanian	Sequanien Rauracien Argovien				
				Oxfordian Callovian			Lower Oolite of Haug	Brown Jura (Dogger)	
			Middle Jurassic	Bathonian Bajocian					Asphaltic impregnations in Sandstones in the Jura Mts.
			Lower Jurassic (Lias) — Upper Lias	Aalenian Toarcian				Black Jura (Lias)	
			Middle Lias	Domerian Plienbachian	Charmouthien				Oil in Germany in this horizon
			Lower Lias	Sinemurian Hettangian					
			Infra Lias	Rhetian					
		Trias	Upper Triassic			Trias (Germanic Divisions)			
				Norian		Keuper			Oil at Gabian; gas at Vaux-Ferous, Jura, Asphalt at Bastennes and St. Martin de Hinx, Oilseep at St. Boès, Aquitanian basin. Oil indications in Algeria & Germany
				Carnian					
			Middle Triassic	Ladinian		Muschelkalk	Lettenkohle main Muschelkalk Anhydrite group Wellenkalk		
				Virglorian					
			Lower Triassic	Werfenian		Bunter Sandstone	Röt Main Bunter S. Lower " "		
Paleozoic	Primary	Permian		Thuringian Saxonian Artinskian			Anthracolitic of Haug		Bituminous shales in many places.
		Carboniferous		Ouralian Moscovian Dinantian	Viséen Tournaisien				
		Devonian		Famennian Frasnian Givetian Eifelian Coblentzian Gedinian	Emsien Siegenien				
		Silurian		Gothlandian Ordovician					
		Cambrian		Postdamian Acadian Georgian					
Pre-Cambrian		Algonkian Archean							

Fortunately, the nation's able geologists have been studying the subject for more than a century and the literature of the Société Géologique de France and other institutions is replete with learned discussions, so that the study of any area can be systematically grounded.

It should be borne in mind that the present writer, although having lived in France and having spent much time in studying its geology, is not a final authority on it. Any person who wishes to study French geology can not do better than begin by reading the three-volume work by Haug,[1] and the book by de Launay,[2] both of which should be kept constantly before him during any investigations. Nobody should suppose that this complicated subject (which French geologists required years to master) can be grasped by a foreign geologist during a few months of residence or that the foreigner is likely to compete very successfully in solving problems on which French geologists have worked and debated for a century. Perhaps an apology may be due to those investigators for endeavoring to cope with the subject at all on the basis of such short acquaintance. Nevertheless, the writer is of the opinion that the oil possibilities of France may wisely be summarized for information of petroleum geologists as a part of their study of world reserves. Table II is a summary of the pertinent stratigraphic divisions represented in the country.

In attempting to make a few generalizations as to probable oil occurrence in France a somewhat more detailed subdivision of the country

TABLE III

GEOLOGIC PROVINCES RECOGNIZED

Number on Figure 1	*Names Given Herein to Geologic Provinces*
1	Rhine graben
2	Limagne graben
3	Jura Mountains
4	Saône-Rhône Valley
5	Alpine region
6	Languedoc-Dauphiny basin
7	Provence
8	Aquitanian basin
9	Paris basin
10	Basin of Autun
11	Basin of Aumance
12	"Massif Amoricain"
13	Vosges Mountains and French Lorraine
14	"Massif Central"
15	Pyrenees Mountains

[1]Emile Haug, *Traité de Géologie* (Paris, 1922), 2021 pp.

[2]L. de Launay, *Géologie de la France* (Paris, 1921), 501 pp.

into geologic provinces is here given than has hitherto been attempted, although in general the system of Redfield is used. The writer's conception of the logical units of discussion is outlined in Table III and in Figure 1.

Of the 15 geologic provinces recognized in this study, only the first 8 evince any notable oil indications, and commercial developments are limited to the first and sixth areas on the list. Commercial asphalt de-

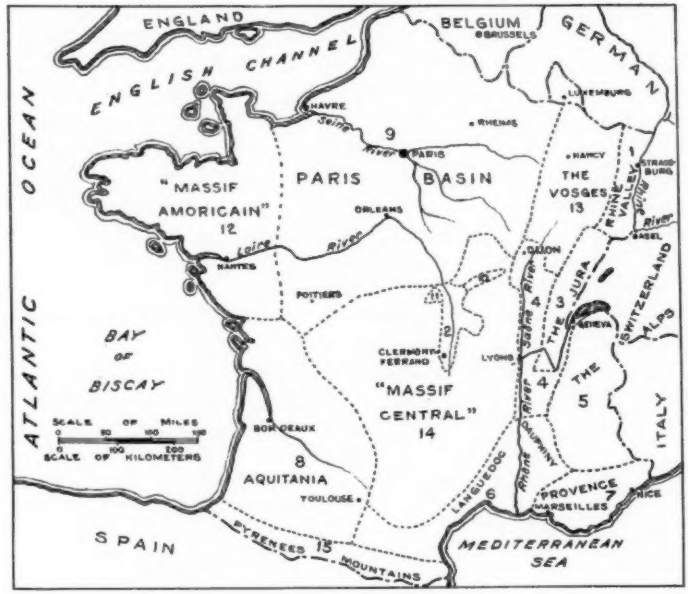

FIG. 1.—Geologic provinces recognized in this paper. 1. Rhine graben. 2. Limagne graben. 3. Jura Mountains. 4. Saône-Rhône Valley. 5. Alpine region. 6. Languedoc-Dauphiny basin. 7. Provence. 8. Aquitanian basin. 9. Paris basin. 10. Basin of Autun. 11. Basin of Aumance. 12. "Massif Amoricain." 13. Vosges Mountains and French Lorraine. 14. "Massif Central." 15. Pyrenees Mountains.

velopments have taken place in the second, third, and eighth areas, and oil shales have been worked in the seventh, tenth, and eleventh.

RHINE GRABEN

Geographical description.—The principal oil-producing district of western Europe is in the Department of Bas-Rhin in eastern Alsace in-

termediate between the Vosges Mountains of France and the Black Forest of Germany. The petroliferous area extends from the vicinity of Basel in Switzerland northward along the Rhine into Germany. Developments are at present concentrated in the vicinity of Péchelbronn (Fig. 2)

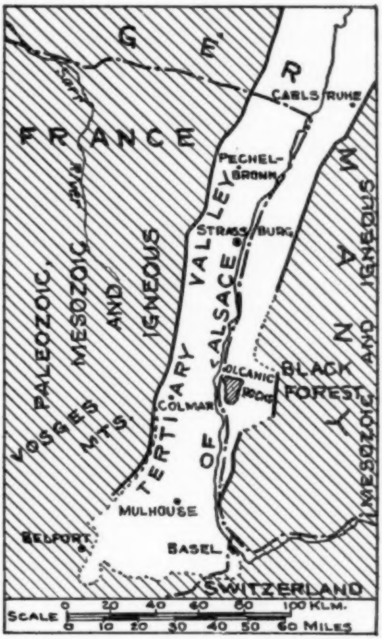

FIG. 2.—Sketch map of Rhine graben (rocks of Tertiary age indicated by absence shading), after de Launay.

about 25 miles north of Strassburg, but a large area from south of Haguenau north to Lobsann has been proved and there are some other centers of minor operations.

It may seem surprising that such a well known name as Péchelbronn does not appear on an ordinary atlas. The fact is that this relatively small village could only be shown on a map of large scale. The Péchelbronn field has been described by de Chambrier (15-21), Daubrée (32), Favre (42), Gignoux and Hoffman (56), and in many works of a general nature.

Stratigraphy and structure.—The formations of the Rhine Valley are largely Eocene and Oligocene in age, but Mesozoic rocks exist on its borders and underlie it at depth. The area is a graben, depressed between north-south faults and cut by a great many minor faults which divide it into numerous blocks, in association with which some anticlinal structure has been mapped. The oil, however, is produced from lenticular sands a few feet in thickness interstratified in Oligocene marls and limestones that aggregate more than 5,000 feet in thickness. Few of these sand lenses exceed 1,000 feet in length, 500 feet in breadth, and 12 feet in thickness. Comparatively little gas accompanies the oil. The section in Table IV, compiled from Gignoux and Hoffman (56), is fairly representative of the strata at Péchelbronn.

TABLE IV

TYPICAL GEOLOGIC SECTION AT PÉCHELBRONN
(By W. P. Haynes, compiled from Gignoux and Hoffman)

	Thickness in Meters	*Oil Indications*
OLIGOCENE		
STAMPIAN		
Meletta beds (shallow marine facies,) Maximum	400	Oil at Schwabwiller and Schweighausen
Fish shales	6	
Foraminiferal marls (deeper marine facies)	30	Bituminous sands near Drachenbronn
SANNOISIAN		
Upper Péchelbronn beds(northern facies, fresh-water conglomerates and sandstones, 280; southern facies, marine, lagunal, and fresh water alternating, 230)	230-280	Bituminous sands of Lobsann mines Numerous oil horizons in Péchelbronn (mostly heavy oil type)
Fossiliferous zone (shallow marine)	70	
Lower Péchelbronn beds (alternating marine, lagunal, and fresh water)	100-130	Numerous oil horizons in Péchelbronn (light oil type)
RED BEDS (saline lagunal)	50-120	No oil
DOLOMITIC ZONE (alternating lagunal, marine, and fresh water)	235-270	Oil at Merkwiller, Biblisheim, et cetera

Surface indications.—Oil has been known for more than a century in an ancient seepage at Lamperstock and numerous traces of oil and asphalt are found at other points in the district. Near Zabern traces are reported in much faulted beds, and Mesozoic bituminous strata are exposed along the front of the Vosges Mountains. Oil is also reported

by Lecomte-Denis to have been found by digging as far south as Gebweiler, in the Department of Haut-Rhin, and asphalt at Lobsann, 2 miles north of Péchelbronn (81). Near Hirtzbach, south of Altkirch, in upper Haut-Rhin, oil and bitumen float on the Oelbach, which means "oil stream." Numerous other surface indications are reported both on the French and German sides of the Rhine.

History of development.—Péchelbronn is of interest as being perhaps the oldest producing field in the world, as claimed by de Chambrier (20). Although development was attempted as long ago as 1627, the enterprise was unsuccessful. In 1700, however, an attempt was made to refine the oil with the object of selling it to Frankfurt druggists, but the project was brought to an end by the War of the Spanish Succession. In 1754 an Alsatian student wrote his doctor's thesis on the subject of Péchelbronn oil and he afterward set up a primitive refinery and produced what we now call gasoline. A Graeco-Russian adventurer then built a refinery that proved successful, and in 1740 a French company commenced to exploit the field. The well which was operated by a student 197 years ago is credited with having produced 50,000 tons of oil up to about 1918.

By 1765 the galleries (in part now abandoned) by means of which the oil was mined had attained a total length of 1,500 feet. In 1785 the Le Bel family undertook developments and sunk pits 80-160 feet deep. For a long time Monsieur Le Bel controlled the Péchelbronn concession; but from 1870 to 1918 Alsace was German territory, Le Bel was forced to sell to a Germano-Alsatian company, and in 1889 the Pechelbronner Oelbergwerke was founded. In 1906, for a consideration of 12,000,000 marks, the field was transferred to the Deutsche Tiefbohrgesellschaft, operating through its subsidiary, the Vereinigte Pechelbronner Oelwerke. Feverish promotion followed, resulting in drilling wells without regard to possibilities, money was squandered, indictments followed, and only the Berlin lawyers profited.

In 1911 the Tiefbohrgesellschaft was converted into Deutsche Erdoel A.-G., which carried on the business until 1919. In that year the French Government took hold, and in 1920 handed the property to the Société Alsacienne des Études Minières, formed for the purpose. In 1921 this company yielded its place to the Société Anonyme d'Exploitations Minières de Péchelbronn, with head offices in Strassburg. This is the company which now operates the field.

Referring to the antiquity of development, de Chambrier mentions an article by T. R. House, who credited the Péchelbronn refinery with

being the oldest plant of the sort in the world, contradicting the assumption of F. C. Thiele, who referred to Volume III of Engler and Höfer's *Das Erdöl*[1] and stated that oil refining was practiced in the Causasus earlier than in Alsace. De Chambrier admits that experiments in oil consumption were conducted at Baku prior to 1723, but he claims that crude refining was practised at Péchelbronn as early as 1627 by a contractor and in 1700 by an Alsatian refiner. In the archives of Péchelbronn can be seen a copy of a drawing, completed in 1768, of an object designed to supply "petroleum oil burning in lamps without leaving any nasty smell." De Chambrier contended that no other country in the world had been mining and refining crude petroleum for 186 years.

In 1796 the "grease" (as Alsatian petroleum was called) was used to lubricate ammunition wagons. The year 1813 marked the sinking of 142 wells to depths of about 640 feet, serving as guides for later mining operations, and, in 1882, leading to the discovery of a gusher which had an initial production reported as 500 barrels per day.

Drilling and production.—The depths to the richest oil sands at Péchelbronn range from 400 to 1,500 feet below the surface. The scale of development may be judged by the fact that the Georges shafts, which had nearly a mile of galleries, were abandoned in 1877, the Henry shafts, having ½ mile of galleries, in 1880, and the André shafts, having 3,800 feet of galleries, in 1888. By the year 1889 about 332 wells had been sunk, and from 1906 to 1918 a thousand more were drilled, between 1,000 and 3,300 feet in depth, and more than half of them (depth 1,000-1,200 feet) were productive.

The Péchelbronn producing territory is estimated to cover 6,000 acres, on which 3,500 wells had been drilled to 1923. The average depth has been 1,300 feet, although some wells were more than 3,000 feet deep. If this field were situated in the United States the cost of recovery would reach several dollars per barrel,—prohibitive in competition with flowing oil; but, according to the French, Alsatian development is considered profitable. Apparently the German management failed to recognize the full value of the field, but the French owners are not likely to make the same mistake.

The figures in Table V are compiled from various sources.[2]

[1]C. Engler and H. von Höfer, *Das Erdöl* (Leipzig, 1913), in 3 vols. and folio of maps.

[2]During the years 1812-1911 inclusive, from Paul de Chambrier, *Historique de Péchelbronn* (Paris and Neufchatel, 1919), 329 pp.; 1912-1928 from André Pellissier, "La production du pétrole en France," *l'Europe Nouvelle*, Vol. 12, No. 618 (1929), p. 1676; and from 1929-1930 from *Statistique de l'Industrie Minière de France.*

TABLE V

PRODUCTION OF CRUDE OIL AT PÉCHELBRONN, 1812-1931

Year	*Production (Metric Tons)*	*Year*	*Production (Metric Tons)*	*Year*	*Production (Metric Tons)*
1812	97.6	1856	72.5	1900	22,597
1813	85.6	1857	75.5	1901	20,093
1814	77.5	1858	65.5	1902	20,206
1815	67.6	1859	64.0	1903	21,615
1816	89.5	1860	75.5	1904	22,633
1817	?	1861	77.6	1905	21,144
1818	73.8	1862	79.2	1906	22,023
1819	64.6	1863	83.0	1907	25,995
1820	49.2	1864	85.5	1908	28,730
1821	60.3	1865	78.0	1909	29,422
1822	?	1866	85.0	1910	33,492
1823	?	1867	124.4	1911	43,748
1824	?	1868	138.4	1912	47,176
1825	83.7	1869	128.5	1913	49,584
1826	?	1870	167.5	1914	49,054
1827	70.0	1871	211.4	1915	43,176
1828	84.2	1872	272.8	1916	41,579
1829	78.0	1873	613.5	1917	46,911
1830	123.1	1874	735.8	1918	51,193
1831	141.5	1875	683.8	1919	47,255
1832	144.9	1876	480.9	1920	54,910
1833	123.0	1877	824.3	1921	55,575
1834	195.8	1878	789.5	1922	70,110
1835	111.2	1879	1,805.1	1923	70,695
1836	108.7	1880	1,028.7	1924	70,869
1837	131.5	1881	1,202.8	1925	64,650
1838	151.6	1882	2,138.0	1926	62,347
1839	127.4	1883	1,142.0	1927	68,642
1840	118.0	1884	2,775.	1928	71,725
1841	122.8	1885	3,086.	1929	73,658
1842	114.1	1886	7,689.	1930	73,593
1843	82.0	1887	7,892.	1931	73,262
1844	86.0	1888	9,049.		
1845	77.8	1889	6,531.	Total	1,720,208.7
1846	82.0	1890	12,977.		
1847	81.0	1891	12,817.		
1848	65.0	1892	12,952.		
1849	70.0	1893	12,608.		
1850	70.0	1894	15,632.		
1851	70.0	1895	15,431.		
1852	72.0	1896	18,629.		
1853	71.0	1897	20,883.		
1854	75.0	1898	23,185.		
1855	70.0	1899	23,415.		

Table VI gives the distribution of this production between wells and galleries in recent years.

Methods of operation.—German sources tell us that the original discoverer of the method of mining oil was a native of Aix named Schneider, but real progress in oil mining is largely due to the Swiss engineer, Paul

TABLE VI

DISTRIBUTION OF PRODUCTION BETWEEN WELLS AND GALLERIES, 1912-31

Year	*From Drilled Wells (Metric Tons)*	*From Shafts and Galleries (Metric Tons)*	*Total (Metric Tons)*	*Equivalent in Barrels*
1912	47,176		47,176	329,156
1913	49,584		49,584	345,957
1914	49,054		49,054	342,250
1915	43,176		43,176	301,248
1916	41,579		41,579	290,105
1917	39,124	7,787	46,911	327,307
1918	32,019	19,174	51,193	357,184
1919	30,298	16,957	47,255	329,708
1920	42,025	12,885	54,910	383,118
1921	43,825	11,750	55,575	387,758
1922	45,150	24,960	70,110	489,171
1923	33,226	37,469	70,695	493,946
1924	38,513	32,356	70,869	495,162
1925	37,155	26,495	63,650	444,723
1926	38,553	23,794	62,347	435,618
1927	39,164	29,478	68,642	473,424
1928	37,739	33,986	71,725	502,075
1929	38,540	33,120	71,662	501,634
1930	41,506	32,300	73,806	516,642
1931			73,262	512,834
Totals	767,406*	342,511*	1,183,181	8,259,030

*Figures for 1931 are missing.

de Chambrier. On account of the notoriety that has been occasioned by the mining method, many persons do not realize that a considerable part of the Péchelbronn oil is recovered by means of ordinary wells. Although some of these flowed oil and water for a short time, the greater part of the oil taken from them has come by pumping, and new drilling is continually under way, as in any field.

After the war, mining was resumed by means of shafts and galleries, oil being allowed to run from the pit faces and from horizontal and diagonal drill holes a few feet in length into sump pits, whence it is pumped to the surface. The sand that is raised to the surface is washed with hot water to remove the oil. Actual operations are said to prove that only 16.67 per cent of the oil can be removed by means of wells, 43.33 per cent additional by means of galleries driven across the zones tested by drilling, and 40 per cent remains in the earth until removed by subsequent mining and retorting of the rock.

Character and refining of oil.—The character of Alsatian oil varies considerably from place to place. In general, the heavier grades are found in the north and the lighter oils in the southern part of the oil-

bearing district. The specific gravity varies from 0.872 to 0.926, but it is rarely more than 0.900. In addition to variation from place to place the character differs in depth at any point, a fair illustration of which is furnished by Table VII. The crude of specific gravity 0.910 yields,

TABLE VII

VARIATION IN CHARACTER OF OIL WITH DEPTH

Depth (Meters)	*Description*	*Gravity (Degrees A. P. I.)*
150-200	"Asphalt grease"	14.4
230-330	Viscous dark brown to heavy	14.7-21.6
350-1,500	Light	24.9-34.6

without cracking, 7 per cent gasoline, 24 per cent kerosene, 9 per cent gas oil, 31 per cent lubricants, and 2.5 per cent paraffine, the remainder consisting of bitumen, coke, and combustible products.

Under German ownership there were four refineries in the Alsatian oil district, of which that at Péchelbronn had an annual capacity of 24,000 tons; at Soultz-sous-Forets, 3,000 tons; at Biblisheim, 10,000 tons; and at Durrenbach, 5,000 tons. The French owners have, however, combined the refining facilities in a single plant at Péchelbronn, which produced more than 80,000 tons in 1928. A comparison of the combined output of the various products in 1895 and 1919 is given in Table VIII.

TABLE VIII

COMPARISON OF OUTPUTS AT DIFFERENT PERIODS

Output in 1895	*Metric Tons*	*Barrels*
Illuminating oils	3,634	25,438
Lubricating oils	2,281	15,967
Gas oil	1,500	10,500
Other products	2,798	19,586
Output in 1919		
Gasoline	1,865	13,055
Kerosene	9,935	68,545
Refined oils	5,760	40,320
Unrefined oils	4,783	33,481
Dark lubricating greases	11,326	79,275
Other products	5,303	37,121

Remarks on areas distant from Péchelbronn.—Drilling for oil has not been confined to the vicinity of Péchelbronn, however. Several unsuccessful test wells have been sunk elsewhere in Alsace; and, among others, an area in Haut-Rhin is described by Jung (75). Two miles south of Wittelsheim, in the Department of Haut-Rhin, two wells—3,670 and

3,526 feet deep—were drilled in 1904 in search of oil, but found potash instead. Although salt has been known beneath the Rhine Valley since the year 1869, at which time it was encountered in a boring about 300 feet deep at Dornach near Mulhouse (49), the existence of salt domes was, according to Friedl (48), unknown until recently, and the salt deposits were thought to be flat or to dip gently with a moderate amount of folding and faulting.

In the area where potash is mined, near the edges of the basin, the depths to the top of the salt range from 650 to 2,700 feet below the surface and no domes are known. In the center of the basin the salt lies normally 3,300-3,600 feet below the surface and the beds are fairly flat except in a few places. At Meienheim is an elongate salt dome parallel with the edge of the graben, and the top of the salt is within 500-600 feet of the surface of the earth. A second dome is reported by C. Schlumberger to have been discovered by electrical explorations at Hettenschlag, farther north on a prolongation of the axis of the Meienheim dome. Gypsum was encountered on it at a depth of 215 feet and rock salt at 330 feet.

Summary.—The reader will readily understand that, although the Rhine Valley may not constitute a relatively important petroliferous province so far as the entire world is concerned, it is important to France. The oil that has been developed and extracted during the past 200 years does not, by any means, bring the end of the Alsatian oil industry within sight, for other parts of the valley have lenticular sand conditions similar to those in the vicinity of Péchelbronn and undoubtedly await development. The very fact that the curve of production is mounting, decade by decade, proves the success of the methods that are used and indicates a bright future for the valley.

As oil has been developed by drilling and mining at rather widespread points in Bas-Rhin, and as many of the surface indications throughout the graben lie outside of producing areas, it seems probable that new and perhaps deeper productive areas will be found from time to time.

LIMAGNE GRABEN

Geographical description.—The region known as the Limagne lies in the Auvergne, 250 miles west of the Rhine Valley, along Allier River and its tributaries, extending from Royat and Clermont-Ferrand in the Department of Puy-de-Dôme northward through the district intermediate between Vichy and Thiers on the east and Clermont-Ferrand and Gannat on the west. The Allier flows in a broad and fertile valley about 30 miles

wide, between the Chaine des Puys on the west and the Monts du Forez on the east, both of which constitute parts of a vast metamorphic and crystalline complex known as the Massif Central. Although oil indications in the Limagne have been described by Glangeaud (59), de Launay (79), and others, the best exposition in the English language of conditions in this geologic province is a paper by Werenfels (135).[1]

Structure and stratigraphy.—Like the Rhine district, that of the Limagne constitutes a north-south graben containing a thickness of perhaps 5,000 feet of sediments dropped down between bounding faults in the metamorphic and crystalline complex. As in the Rhine graben, the beds here are largely of Oligocene age, cut into blocks bounded by north-south faults. Unlike conditions in the Rhine district, however, outbursts of basic lava and volcanic ash took place extensively in the Limagne. These resulted, on the surrounding plateaus, in the formation of *puys* or craters, reflected inside the graben by cones ranging from a few feet to a maximum of 262 feet in height, as Puy-de-Crouelle. A few of these cones have craters at their summits. Werenfels (135) writes:

> The existence of a slight doming of the Oligocene beds around these basalt necks mentioned is not impossible, but even if this intrusion did not cause any doming of the sediments, there will be a disturbed and shattered zone of rocks around these volcanic necks, where petroleum could accumulate in the fissures and openings of the basalt breccia and sediments.

The geography of the district is illustrated in Figure 3.

Two main lines of faulting bound the graben, and minor faults in the valley itself are marked by numerous necks, ranging in age from Miocene to Pleistocene. Associated with them are tuffs and agglomerates and a certain interstratified material called by French geologists "pépérite,"[2] consisting of basaltic matrix containing basalt, granite, and limestone fragments, interstratified in places with thin and brittle paper-shale and other lenticular layers. This pépérite yields liquid bitumen in the form of globules, stringers, and vein-like masses in numerous exposures to such an extent that Glangeaud considered the bitumens eruptive, like the lavas which they accompany.[3]

Surface indications.—Attention was called to liquid asphalt at Puy-de-la-Poix and elsewhere in the Limagne by Antoine Delarbre of Clermont-Ferrand in 1785. Definite indications of the occurrence of oil have since been found to cover an area of nearly 1,000 square miles of

[1]Since this paper was written, another good discussion has appeared, by Barrabé (2-A).

[2]For full description of these outcrops see Ph. Glangeaud, "Les Régions volcaniques du Puy-de-Dôme," *Service Carte Géol. France*, Vol. 19, No. 123 (1908), pp. 96-98.

[3]*Ibid.*, p. 99.

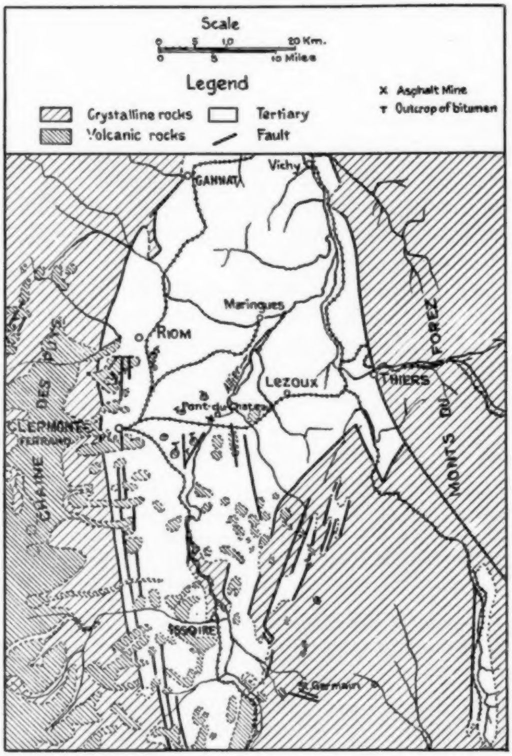

FIG. 3.—Sketch map of Limagne graben (rocks of Tertiary age indicated by absence of shading), after de Launay *et al.*

the upper end of the graben. The types of these occurrences are classified in Table IX.

The first three types of occurrence are conspicuous in railroad and highway cuts, in surface exposures and quarries at a score of localities. The fourth type is to be seen at Pont-du-Château, 8 miles east of Clermont-Ferrand, where between 6,000 and 19,000 tons of bituminous limestone are retorted annually and used in paving. The mines underlie an area estimated at ¼ square kilometer, and liquid bitumen also runs direct from the rock into sump holes from which it is collected. The

TABLE IX

CLASSIFICATION OF SEEPAGES IN LIMAGNE

1. Blotches and stringers of liquid asphalt or bitumen in Oligocene limestone outcrops at Lempdes, L'Escourchade, Menat, Augnat and Pompignat
2. Bituminous dikes, stringers, and oozings of semi-fluid bitumen from basalt or basalt-breccia or pépérite in or on edges of plugs or necks at many places
3. Sands strongly impregnated with bitumen to a thickness of several feet and of unknown depth on exterior of necks, where tuffaceous beds have quaquaversal attitude
4. "Oil mines" having extensive galleries extending down-dip from formation outcrops. Semi-fluid and fluid bitumen is extracted, transported, and refined in quantity for highway purposes. Mines at Pont-du-Château
5. Escapes of gas, both observed carbonic and reported "petroleum gas" from a well, from a cave, and from places in the Pont-du-Château oil mines
6. In vesicles of basalts
7. Bitumen is reported to impregnate arkose or arkosic sands at Lussat and at Chamailleres near Royat
8. Thin bed of chocolate-brown bituminous shale, which will burn, has been retorted since 1931 at Menat, where 1,400-2,200 tons are mined annually, yielding about 16 gallons of oil per ton when used in that manner

productive stratum, cut by small faults, dips away from a near-by neck at an angle of 4° or less. The richness is reported to increase down-dip until as much as 12 per cent of the rock is bitumen. Limestone impregnated with liquid bitumen can also be seen at Lempdes, L'Escourchade, Menat, Augnat, and Pompignat. At Ruys it is irregularly disseminated in Aquitanian limestone (81). At Lussat, according to Lecompte-Denis, shales containing a notable percentage of bitumen are exploited in the midst of more or less arkosic sands. At Malintrat a vein 2½ feet wide, plunging at an angle of 85°, filled with fragments of wall-rock cemented by bitumen, is exploited by galleries. At Machaut, east of the road from Clermont-Ferrand to Riom, is a plug having on its perimeter a mass of agglomerate cemented by bitumen. Gas exudations are reported to take place associated with bitumen at Puy-de-la-Poix. At Puy-de-la-Bourriere bitumen is found in rocks of known Upper Tongrian age, according to one writer. Many more examples might be cited, but these are sufficient to show the widespread occurrence of surface indications in the Limagne.

Development in Limagne.—The first publication referring to oil in the Limagne was in *La Nature* on January 7, 1893 (87). Bitumen development commenced in 1831 and many concessions ensued, resulting in the formation of the Société des Sources et d'Asphalte du Centre, of which the principal operations are at Pont-du-Château. The bitumen in the rock at that place ranges from 9 to 18 per cent.

In 1892, a series of test wells was commenced by M. de Clercy—the first well (220 meters deep) being sunk on the right of Allier River not far

from the Pont-du-Château mines. The Macholles well, completed in 1896, is one of the most important in the Limagne, having good showings of heavy oil. In 1919, on advice of Monsieur de Launay, researches

TABLE X

WELLS DRILLED IN LIMAGNE

No.	Description	Depth (Meters)	Depth (Feet)	Reported Result
1	Shaft at Clermont having a horizontal gallery of 102 feet....	36	118	
2	Near Pont-du-Château	320	1,050	Showings of gas and bitumen
3	"Well No. 1" at Puy-de-la-Poix	107	351	Traces of oil
4	"Well No. 2" at Puy-de-la-Poix	40	131	Traces of oil and gas
5	Gandailat well ("No. 3"), about 2 miles southeast of Clermont-Ferrand.............	103	338	Traces of oil
6	Pont-d'Aubierre well ("No. 4"), about 2 miles southeast of Clermont-Ferrand..........	69	226	Traces of oil
7	Macholles well, 2½ miles southeast of center of Riom......	1,164	3,808	Bitumen and a few liters of heavy oil at 2,093 feet in Oligocene beds and heavy oil at 3,657 feet
8	Pont-Battu well, near Macholles well......................	276	903	
9	Les Martres-d'Artières well....	453	1,490	Showings of bitumen and non-inflammable gas; and at 224 feet got geyser of hot water and chunks of sulphurous bitumen
10	Pont-de-Crouelle, 3 miles east of Clermont, between Puy-de-la-Poix and Puy-de-Crouelle...	856	2,808	Had many showings and about 7 barrels of oil at 1,955-1,960 feet
11	Mirabel well, 1½ miles southwest of Riom..............	1,322	4,336	Reported that 50 barrels or more of liquid bitumen were bailed and shipped from it
12	Grand Beaulieu well ("No. 5"), about 2 miles southeast of Clermont.................	1,154	3,685	Traces of oil
13	Gimeaux well, midway between Gimeaux and Yssac-la-Tourette, northwest of Riom.....	351(?)	1,155(?)	
14	Cellule well, midway between highways and west of railroad east of Gimeaux and north of Riom....................	360	1,181	
15	Lussat well, midway between les Martres-d'Artières and Lussat	208	682	Showings of gas
16	Barnier well, east of Lussat....	139	457	
17	Ruchon well, southeast of Lussat	23	77	
18	Arbaux well, west of Puy-de-la-Poix and east of Clermont...	47	154	
19	Chamallieres................	82	269	Showings of gas and bituminous odor

were commenced and a well drilled at les Martres-d'Artières and another at Puy-de-Crouelle. Table X gives a list of wells that are known to have been drilled in the Limagne.[1] Outside of the few barrels mentioned in Table X, there has been no oil production in the Limagne. Table XI gives, in incomplete figures, an idea of the production of asphaltic limestone according to *Statistique de l'Industrie Minière*.

TABLE XI

PRODUCTION OF ASPHALTIC LIMESTONE IN DEPARTMENT OF PUY-DE-DÔME

(*In Metric Tons*)

Year	*Production*	*Year*	*Production*
1886	1,235	1909	11,453
1887	413	1910	16,106
1888	421	1911	12,080
1889	243	1912	15,367
1890	505	1913	20,130
1891	1,628	1914	13,682
1892	3,420	1915	3,782
1893	2,326	1916	7,433
1894	6,010	1917	6,679
1895	6,987	1918	6,148
1896	8,664	1919	8,552
1897	8,653	1920	10,784
1898	9,007	1921	13,819
1899	9,858	1922	18,020
1900	12,567	1923	12,394
1901	7,193	1924	14,083
1902	6,625	1925	17,010
1903	8,645	1926	15,920
1904	9,944	1927	19,000
1905	9,846	1928	18,443
1906	10,743	1929	18,676
1907	11,733	1930	19,000(est.)
1908	13,854		
Total......................			449,081

Character of oil and gas.—Little is known about the character of oil that might be found at great depth in the Limagne graben, but that thus far developed in the Mirabel, Crouelle, and Puy-de-la-Poix test wells and the Pont-du-Château mine has been heavy, sticky, and dark. The oil from the Crouelle well had a gravity of 16° Bé., contained 9.3 per cent of sulphur, and an average of 16.5 per cent of volatile products at a temperature of 518°. Some reports indicate showings of lighter oil at greater depth, but these are not fully substantiated. The reported composition of gas which emerges from the artesian water well at les Martres d'Ar-

[1]The depths given should be accepted only with the understanding that they are gathered from various sources all of which do not agree, and they are of general interest without being known to be accurate in all details.

tières is given in Table XII. This gas was piped to a near-by building, where it was bottled and shipped for use in making soda-water.

TABLE XII

COMPOSITION OF GAS FROM ARTESIAN WELL AT LES MARTRES D'ARTIÈRES

Substance	*Percentage*
Carbon dioxide	98.80
Oxygen	.02
Methane	.12
Nitrogen	1.15
Total	100.09

Summary.—Because of the failure of all wells drilled to date to develop commercial oil production, it may be surmised that the Limagne will not become a valuable producer of oil. However, this view can not be accepted as definitely proved. The vast bituminous accumulations indicate the presence, in past time, of much petroleum under this valley. The association of bitumen with igneous intrusions indicates that the ultimate source of bitumen and oil may lie at considerable depths below the bottoms of wells that have been drilled. Furthermore, the occurrence of petroleum in rocks of Triassic age in the Department of Hérault on the south furnishes a clue to the desirability of deeper drilling in the Limagne.

So far as investigations have gone, there is no certainty of the existence of distinct anticlinal or domal structure. The surface of the graben is so flat that little can be learned, without gravimetric, seismic, or magnetic surveys, of the attitude of deep subsurface beds. Considerable folding may exist, as it does in other grabens of the world. Clearly the Limagne needs further geological and geophysical studies on the part of petroleum geologists.

JURA MOUNTAIN REGION

General description.—The region of the western French Jura may be described as the mountainous area that lies intermediate between Lyons on the west, Geneva on the east, Grenoble on the south, and Dijon, Belfort, and Basel on the north. The geologic province covers large parts of the departments of Ain, Jura, and Doubs, and topographically flanks the basins of Neuchâtel, Geneva, and Bourget on the west and north. The country is a series of plateaus and mountain ridges that supply high pasture lands and pine forests, forming a steep and rocky front on the Swiss side along a line extending from Neuchâtel southwest to Belle-

garde and south to the big bend of the Rhône northwest of Chambery. The Jurassic period derives its name from these mountains, some of which exceed a mile in altitude. The Doubs, Ain, and Rhône constitute the principal streams.

Stratigraphy and structure.—Although composed largely of Jurassic, Cretaceous, and Tertiary rocks, the region exposes the Triassic in a few places due to faulting and folding. The mountains consist of a great north-south to northeast-southwest series of anticlines, highly folded and in places overthrust on their western side.

Professor Riche of the University of Lyons studied the oil problem of this region for 40 years and found the structure to be very complicated. The Jurassic in particular is highly fractured, expecially in the vicinity of Ambérieu where five faults can be seen within a distance of 4 kilometers. We are told (79) that a fault, 3 kilometers southeast of Ambérieu, places the variegated marls of the Triassic in contact with the Bajocian of Middle Jurassic time. Studies of the French Jura have been made by many geologists, but seldom from the standpoint of the occurrence of oil and gas.

Surface indications.—Bitumen is found in this geologic province in Bathonian, Kimeridgian, Urgonian, and Barremian rocks of Jurassic and Lower Cretaceous ages. Surface indications in the Jura consist of (1) gas wells and (2) asphalt-impregnated sandstones and limestones. A zone of Lower Cretaceous bituminous limestone extends from Mussiege along the east slope of Mount Vuache and the Chaine du Reculet, and as much as 1,900-6,500 tons of rock have yielded 6-7 per cent of bitumen in recent years. Asphalt-impregnated limestones at Chézéry, Challonges, Forens, Lelax, Confort, Pyrimont (Seyssel), and Bellegarde extend almost continuously along the valley of Valserine River into Switzerland, where bitumen has been exploited at Val Travers since the 18th century (79). At Seyssel a Lower Cretaceous bed yields 7-10 per cent of oil, and seven similar beds at Pyrimont (on the opposite river bank) are irregularly impregnated with asphalt containing 8.15 per cent of bitumen soluble in carbon bisulphide. Eocene sands are impregnated with bitumen at Boge near Confort. At Corbonad, St. Jean de Chatonad, St. Champ de Chatonais, and Anglefort are bituminous limestones and clays of Jurassic age which yield 47 per cent oil.

Table XIII gives the tonnage of asphaltic limestone produced in the Department of Ain from 1886 to 1929 inclusive. No record is at hand of the output since that time.

Drilling at Vaux-Fevroux and vicinity.—About 60 years ago a test for salt was drilled 3 miles (5 kilometers) southeast of Ambérieu-en-Bugey on Buisin River in the Department of Ain. The well entered Triassic rocks, encountered strong flows of gas 650 feet from the surface and was abandoned, but gas bubbled through water for many years.

TABLE XIII

PRODUCTION OF ASPHALTIC LIMESTONE FROM DEPARTMENT OF AIN
(According to *Statistique de l'Industrie Minière*)

(*In Metric Tons*)

Year	*Production*	*Year*	*Production*	*Year*	*Production*
1886	7,785	1901	10,039	1916	700
1887	5,709	1902	13,289	1917	785
1888	9,513	1903	13,750	1918	1,896
1889	14,745	1904	9,672	1919	2,950
1890	15,528	1905	9,534	1920	4,750
1891	13,735	1906	13,977	1921	6,220
1892	12,016	1907	8,279	1922	4,990
1893	9,988	1908	7,962	1923	4,390
1894	13,469*	1909	12,316	1924	4,540
1895	19,754*	1910	6,565	1925	5,076
1896	14,323	1911	9,372	1926	9,000
1897	10,169	1912	9,578	1927	9,000
1898	14,040	1913	15,208	1928	13,000
1899	12,598	1914	3,698	1929	10,387
1900	7,215	1915	1,560	Total (through 1929 only)	401,070

*Also 481 metric tons of bituminous shale in 1894 and 433 metric tons in 1895.

The Vaux developments have been described in several articles in *La Revue Pétrolifère* (114 and 126), *Chaleur et Industrie* (60), *Journal des Usines à Gaz* (74), and *La Vie Lyonnaise* (6). The Bregi well was completed in 1907 while being drilled for salt. After traversing the Lias and the Triassic gypsiferous marls, the well was stopped at 221.75 meters in dark dolomitic limestone. At a depth of 187.5 meters, there occurred a violent eruption of inflammable gas, estimated as being the equivalent of 10,000 cubic meters (about 360,000 cubic feet) per day.[1] The well was abandoned in 1908 because the flow of gas could not be controlled, and the hole filled with water, but gas flowed to waste for 14 years. Inflammable gas with an oily odor was recently said to continue to bubble from the hole at 10-minute intervals. The pressure of the gas was reported as "60 atmospheres."

[1]Other reports credit the initial production of this well as 7,000,000 cubic feet per day (43) from a depth of 198 meters (618 feet) in soft sandstone.

After the war, under the leadership of M. Benard, La Société d'Études et de Recherches Pétrolifères began drilling on Buisin River. On November 25, 1919, the Société Civile de Recherches de Vaux commenced a well, which stopped at 492 meters (1,614 feet) on May 1, 1921, having first encountered the Middle Lias, then gypsiferous variegated clays of Triassic age at 70.60 meters, resting on Middle Jurassic rocks owing to overthrust faulting. Two small gas pockets were encountered. At 185 meters, in the variegated marls, "8 liters per minute" (406 cubic feet per day) of gas were encountered on top of the *lumachelles du bajocien* (Middle Jurassic).

Well No. 1 of the Société d'Études et de Recherches pétrolifères (which later became the Société de Recherches et d'Exploitations pétrolifères) was commenced on December 26, 1919, 600 meters northwest of the old well of 1906, and on December 15, 1920, had reached a depth of 457 meters (1,499 feet) without success. The Upper Triassic was penetrated to a depth of 70 meters, then the variegated gypsiferous Triassic marls, then friable micaceous sands (probably Miocene) to 271 meters. At 334 meters, some compact pisolitic limestones of Séquanian (Jurassic) age were penetrated. From 390 to 456 meters was the Upper Rauracian and from 456 to 457 the Lower Rauracian, which lie stratigraphically just below the Séquanian.

Well No. 2, of the same company, was commenced in 1920 and yielded 113,000 cubic meters (about 4,000,000 cubic feet) of gas per day at a depth of 217 meters (712 feet) under the *sables greseux* (loosely consolidated sandstones), and in 1924 it was reported that this well was yielding 40,000-50,000 cubic meters (1,400,000 to 1,800,000 cubic feet) of gas per day. It is reported that the well flowed to waste for 3 months, and 2 months after being closed it attained a pressure described as "15.5 kilograms" (about 220 pounds per square inch).

Well No. 3 of this company was commenced in 1922, 90 meters southeast of the old 1906 well and "120 meters from Well No. 2." Its total depth was 409 meters (1,342 feet), and it produced a reported volume of 131,000 cubic meters (4,626,000 cubic feet)[1] of gas per day from a depth of 217 meters (709 feet) in the Upper Triassic, resulting in a settled production of 78,000 cubic meters (2,755,000 cubic feet). Gas from this and a later well (in date of completion) was piped 8 kilometers (5 miles) to Ambérieu and was still being used there at the time of the writer's visit in 1928.

[1]Owing to the various conflicting accounts and the difficulty of knowing with certainty which well is described, the correctness of none of the figures can be guaranteed.

Wells continued to be drilled. No. 4 encountered a feeble flow of gas at 240.8 meters (770 feet) and got production in the gypsiferous Triassic at 602 meters. The total depth was 602.85 meters (1,977 feet). No. 5, commenced on June 15, 1924, and completed on September 30, reached the Keuper (top of Triassic) at 271 meters (889 feet), but produced only 600 cubic meters (about 21,000 cubic feet) of gas per day. No. 6, near Fay, was begun at the end of 1925 and proved a failure at 127.55 meters (418 feet). Table XIV is a summary of the results at Vaux according to the best available information.

TABLE XIV

WELLS DRILLED AT VAUX (126)

No.	*Description*	*Depth (Meters)*	*Result*	*Date Completed*
1	Direction des Salines du Jura....	198	Gas, reported 60 atmospheres pressure; 10,000 cubic meters*....................	1907
2	Soc. Civile des Recherches pétrolifères de Vaux..............	492	Gas......................	1921
3	Well No. 1 of Soc. d'Études et de Recherches pétrolifères (name changed later to Soc. de Recherches et d'Exploitations pétrolifères)......................	457	Showing of gas............	1920
4	Well No. 2 of Soc. d'Études et de Recherches pétrolifères	223	Gas, 113,000 cubic meters per day; pressure, 15.5 kilograms	
5	Well No. 3 of same (between No. 2 and 1907 well).............	406	Gas, 150,000 cubic meters per day; pressure, 13 kilograms	1922
6	Well No. 4 of same (150 meters from No. 2).................	602	Showing of gas............	1924
7	Well No. 5 of same (on left bank near hills)..................	353	Showing of gas............	1924
8	Well No. 6 of same (near Fay)....	128	Failure..................	1925

*Other reports credit this well with 7,000,000 cubic feet (200,000 cubic meters) per day at depth of 188 meters (617 feet).

Geology at Vaux-Fevroux.—The natural gas found at this place is encountered at various horizons in gypsiferous shales of the Keuper series. The region is one of *écailles* (126) or shingle-like faults, subsequently folded, and in one of these "structures" the gas is trapped above a horizontal *charriage* or overthrust fault, the extent of which has not been established except that it apparently does not reach Torcieu, 3 kilometers (2 miles) distant. Vaux River marks the axis of an anticline of which the bordering escarpments are composed of Bajocian limestone. A transverse fault is said to cross the valley northeast and southwest, and other complications may exist.

The drilling at Vaux-Fevroux was studied and closely followed by Professor Riche, who reported that the gypsiferous Upper Triassic marls had been penetrated, and he published an instructive cross section (Fig. 4) through the wells indicating that a minor *charriage* has placed the Triassic above the Jurassic and Oligocene across a breadth of several miles. Rock cores that still existed in the field office in 1928 bear witness to the existence of adequate data for these determinations.

Two of the wells were still capped and in 1928 supplied Ambérieu with gas, the pressure of which, originally 200 pounds or more per square inch, had declined to 56 pounds. The production, originally 3,000,000 cubic feet per day, had dropped to 65,000 cubic feet. A glass factory at Lagnieu, 3 kilometers (2 miles) south of Vaux, supplied with gas for 3

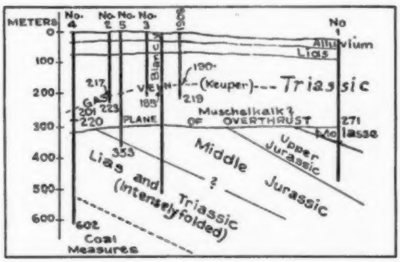

FIG. 4.—Cross section of Vaux-Fevroux gas field and overthrust (after Riche).

months, had to be cut off on account of the early decline of the field. In 1928 gas still leaked around the casings and had an odor of oil and gasoline. Some gasoline has been extracted from the gas in this field. Analyses are given in Table XV.

Wells drilled outside Vaux region.—Only a few wells have been drilled outside of the vicinity of Vaux. On May 3, 1917, the Syndicat d'Études et de Recherches du Bugey commenced a test well at Torcieu, 3 kilometers (2 miles) across the mountains east of Vaux, and on December 4, this well had reached a depth of 1,652 meters (5,418 feet), encountering the Lias at 152 meters and the Triassic at 227 meters. The test passed through 144 meters of Keuper and 99 meters of the underlying Muschelkalk, then 49 meters of *grès bigarrés* (variegated sandstone) and 35 meters of Vosgian sandstone of Lower Triassic age. At 448 meters from the surface, some "showings of gasoline" were reported at the contact of the Muschelkalk and the *grès bigarré*.

TABLE XV

COMPOSITION OF GAS FROM VAUX-FEVROUX WELLS
(Compiled from various sources)

Methane	83.1	77.00	80.00	79.27	80.40
Ethane	1.0		5.47	4.91	1.00
Propane			2.00	3.17	
Isobutane			.17	.14	
Hydrogen	3.4	8.64	4.85	5.24	3.40
Carbon dioxide	.4	1.25	2.40	2.36	2.70
Carbon monoxide		2.00			.40
Oxygen	1.2	2.00			1.3
Nitrogen	10.8	7.4	5.01	4.91	10.80
Total	99.9	98.29	99.90	100.00	100.00

The calorific value ranges from 8,437 to 9,357.

A log of the formations encountered in the Torcieu well is given in Table XVI.

TABLE XVI

LOG OF FORMATIONS ENCOUNTERED IN TEST WELL AT TORCIEU (6)

Age	*Formation*	*Depth (Meters)*
RECENT	Late alluvium	7.1
	"Bajocian débris"	16.0
	"Ancient alluvium"	30.0
LIAS	Charmouthian	151.6
	Sinemurian and Hettangian	167.5
	Rhetian	204.0
TRIASSIC	Upper Keuper	227.0
	Middle Keuper (gypsiferous marls)	303.0
	Lower Keuper	348.25
	Muschelkalk	446.85
	"Variegated sandstone"	495.8
	Vosgian sandstone	591.0
PERMIAN ?		
	Total depth	1,651.8

There seems to be no indication of the Vaux-Fevroux overthrust in the Torcieu well. Another test was made, on the anticline of Pommier and Chessy in the Lyonnaise, encountering Bajocian to a depth of 9.6 meters and Taorcian to 112.5 meters. The total depth was 280 meters. Well No. 2 of the same company was drilled at Chatillon in 1925-6. Another test was sunk at Ambronay, north of Ambérieu, to a depth of 550 meters (1,804 feet). Another test well, on the Bourbre, is said to have penetrated 80 meters of sandstone impregnated with oil, and some oil showings were reported from a well drilled in 1913. In general, however, borings in the Jura region have been few and shallow.

Summary.—The non-discovery, in the Jura region and its vicinity, of fields other than that of Vaux-Fevroux is no indication that they do not exist. In fact, the drilling that has been done has been isolated and unsystematic. Many formations have been shown to contain bituminous indications or gas. Folding, though intense, is no more so than in many petroliferous provinces and in some oil fields. The most favorable anticlines have not been tested by the drill and the extent of the known overthrusting has not been fully deciphered.

It seems probable that additional gas fields and possibly some oil may ultimately be developed in the Jura mountain region and its vicinity, but this will not happen until petroleum geologists have studied the region intensively, which they have not yet done so far as the writer is aware.

LOWER LANGUEDOC BASIN

General description.—Languedoc is the most common name applied to the ancient dominion of the Counts of Toulouse in southern France (Fig. 5). Although the northwestern part of this district is included in the *Massif Central*, the region of interest here comprises the departments of Gard, Hérault, Aude, and southern Ardèche. For convenience, the departments of Drôme, Vaucluse, Bouches-du-Rhône, and the northern part of Pyrénées-orientales are also included. The vicinity of Grenoble, on the contrary, geologically continuous with the Lower Languedoc basin, is discussed in connection with the Rhône valley.

Stratigraphy and structure.—The hills of the Lower Languedoc are composed of Mesozoic and Tertiary strata, generally folded along northeast-southwest axes. In the western part of the Department of Hérault, they are penetrated by igneous intrusions. The oldest stratified rocks in the region, outside the borders of the *Massif Central*, are of Triassic age, in places 300 feet thick, resting on pre-Cambrian schists or upturned edges of strata ranging from Ordovician to Carboniferous in age. The best account in the English language of the geology and oil possibilities of Lower Languedoc is given by Redfield (112).

This basin is traversed by many types of intricate structure. These range from sharp, faulted, tightly closed and overturned anticlines surrounding outcrops of Triassic or Jurassic strata to moderately folded domes covered by Cretaceous or Tertiary. Some anticlines can be traced long distances northeast and southwest. The basin strata of Lower Languedoc are separated from the igneous and metamorphic rocks of the *Massif Central* by important faults.

FIG. 5.—Sketch map of Languedoc and parts of adjoining regions (Paleozoic and ancient igneous rocks indicated by diagonal shading, Mesozoic areas by horizontal shading, and eruptive rocks by solid black), after de Launay.

As in the Aquitanian basin, of which this basin constitutes the eastward extension, the geologic structure is complicated and must be studied from the tectonic perspective furnished by *nappes de charriage* or Alpine overthrusts as well as from the standpoint of surficial anticlines. The valuable works of Termier, Haug, Kilian, Lugeon, and other geologists should be assiduously studied by all investigators.

Surface indications at Gabian.—The best oil seepage in the Languedoc is one that was known and utilized as long ago as 1608.[1] At the time of its maximum production the spring is said to have yielded 2 gallons per day of reddish brown petroleum, having a disagreeable odor and a gravity of 26.5° Bé.; the fluid was collected every 8 days and supplied 70 barrels of oil in a period of 80 years. The seepage, which con-

[1]Rivière, "Memoir on Some Peculiarities of the Lands of Gabian, and Chiefly on the Fountain of Petroleum which Flows There" (Montpellier, 1717).

tinued to exist until recently, was less than a kilometer (½ mile) south of Gabian in the Department of Hérault, about 20 kilometers (12.5 miles) north of Béziers. The spot is on the right bank of Tongue River, a tributary of the Hérault. Gas, which formerly existed under sufficient pressure to cause the wells to flow, reported to consist of almost pure carbon dioxide and thus apparently of volcanic origin, emerges at several places in the vicinity.

History of Gabian developments.—No effort was made to exploit the locality until 1884, when the Gabian Petroleum Company commenced a tunnel which was continued to a total length of 165 feet. In November of the same year the company began actual drilling under the direction of M. Zipperian in a syncline of Upper Triassic strata at a point 400 meters (1,310 feet) south of the seepage. After working 10 months and finding showings of oil, the well was abandoned at a depth of 203 meters (666 feet). In 1886 the same company commenced a second well 900 meters (2,950 feet) north of No. 1 and directly on a Lower Triassic sandstone outcrop, and this hole ultimately reached a depth of 427 meters (1,360 feet) without success.

For 37 years thereafter Gabian was almost forgotten by the oil industry. In 1923, however, a Government mission organized by the Comité Scientifique du Pétrole, Direction des Pétroles et Essences, was sent to prospect the area. The first well in these recent developments was located by geologists Barrabé and Viennot intermediate between two basalt-capped hills, at a point 1,500 meters (4,920 feet) southwest of the old seepage and on the prolongation of a Triassic anticline exposed in the river bed. Oil was discovered on September 11, 1924, and on November 6 of that year the first producing well was brought in. This constituted the first commercially productive oil well in France outside of the Department of Bas-Rhin. The first notation on the subject in technical literature of the English language was a short article by Powers (111). On November 24, 1924, the well was flowing 90 barrels per day. The discovery indicated to geologists the possibility of obtaining additional commercial oil in the "structures" of southern France. A cross section is given in Figure 6.

Details of development.—The subject has been discussed at length by Barrabé (2) and Viennot (3, 128, 130, 132). The successful wells, after passing through cavernous dolomite and gypsiferous marl of Upper Triassic age, obtained oil in Lower Triassic sandstone. One of the tests was drilled through the Permian into underlying Silurian rocks. The greater part of the development has been carried on by the Government,

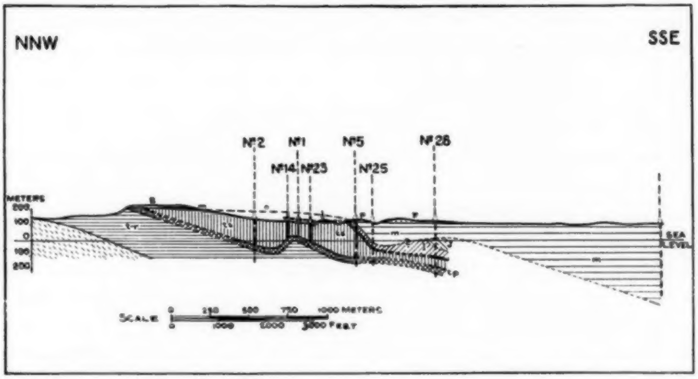

FIG. 6.—Cross section of Gabian field, after Viennot (*t-r*, Permo-Triassic; *tp*, Triassic dolomite breccia (reservoir rock); *ts*, Upper Triassic (Keuper); *l*, Lias; *J*, Middle Jurassic; *m*, Miocene; *P*, Pliocene; *B*, basalt. Wells represented are not situated exactly on line of section).

but, as some of the test wells were privately drilled, Table XVII includes both public and private wells. The lists are complete only to the end of 1927, the time of which Viennot's comprehensive paper on the subject was written (132).

Character and production of oil.—Gabian oil is reported as having a paraffine base with a trace of asphalt; it is dark brown and has a greenish fluorescence. Its average gravity is 37.5° Bé. at 15° C., but it becomes viscous below 12° C., easily congeals and requires heating in cold weather. On distillation the crude oil yields 3.95 per cent gasoline and 26.05 per cent kerosene below 225° C., and by cracking the gasoline has been raised to 48 or 50 per cent. The total production at Gabian during the first 7 years of the field is given in Table XVIII.

Surface indications outside Gabian area.—Indications of petroleum also occur outside of the Gabian area in various formations. Bitumen seeps out of a 5-foot bed of limestone in a railroad cut north of Milhaud and also at Connaux, 16 kilometers (10 miles) northwest of Uzés. Asphalt is reported in Albian and Cenomanian shale (Middle Cretaceous) at Vagnas, elaterite is reported at Laudun, and bitumen is found in Eocene sediments at Barjac. A bituminous spring at Les Fumades, near Alès, is of historic importance.

The most important asphalt-bearing strata of the Languedoc are, however, in the Lower Oligocene. An almost continuous series of Lat-

TABLE XVII

WELLS DRILLED IN VICINITY OF GABIAN TO END OF 1927 (132)

(Wells Drilled by Government)

No.	Altitude of Reservoir Rock (Meters)	Depth (Meters)	Reported Production to January 1, 1928, in Cubic Meters Figures in Parentheses in Barrels (Compare with Table XVIII)
1	+25	106.75	1,549.8 (9,757)
2	−53	192.	Water
3	−138		Water
4	−27		2,879.3 (18,123)
5	−110		
6	−30		6,619.3 (41,666)
7			Dry
8	−90		Showing of oil
9	+17		Showing of oil
10			Dry
11	−11		Showing of oil
12			Dry
13	−87		Showing of oil
14	+13		12,400 (78,058)
15	−19		1,145 (7,208)
16			Dry
17			Dry
18	+14		Showing of oil
19	+17		Showing of oil
20	−55		Showing of oil
21	−17		Showing of oil
22	−18		Showing of oil
23	−33		115.8 (730)
24	−87	363	Dry in Permo-Triassic
25	−86		Showing of oil
26	−3		1,115.1 (7,019)
27	+15		211.3 (1,328)
28	−163	344	Dry in Permo-Triassic
29	−6		Showing of oil
30	−24		7.8 (49)

Wells Drilled by Private Capital

No.	Description	Depth (Meters)	Result
1	Drilled in 1884, 400 meters south of oil spring	203	Dry
2	Drilled in 1886, 900 meters south of No. 1	415	Dry
3	Société de Recherches de Minérais et l'Hydrocarbures, 1 kilometer southeast of Neffies	454	Dry in Permian
4	Société de Péchelbronn, 300 meters east-northeast of bridge at Pouzolles	440	Dry in Miocene
5	Le Pétrole de France, 1 kilometer south of Pouzolles	70	Dry in Miocene
6	Le Pétrole de France, 500 meters east of Magalas	316	Dry in Miocene
7	Société Financière Française et Coloniale, 800 meters northwest of Magalas	360	Dry in Lower Triassic
8	Société de Péchelbronn, 1 kilometer northwest of preceding well	370	Dry in Devonian
9	North of Gabian railroad station	?	Dry in Lower Carboniferous
10	North of Gabian railroad station	?	Dry in Lower Carboniferous

TABLE XVIII

PRODUCTION OF CRUDE OIL AT GABIAN IN METRIC TONS

Year	*Production*
1924	210*
1925	2,000†
1926	5,950†
1927	4,028†
1928	2,185†
1929	2,875†
1930	1,880‡
Total (through 1930 only)	19,128

**Courrier des Pétroles.*
†*Statistique de l'Industrie Minière.*
‡*Annales de l'Office National des Combustibles Liquides.*

torfian bituminous limestones crops out east of a great fault which traverses the Alès basin for many miles to a point beyond St. Jean-de-Maruéjols (81) and has been worked commercially for many years (79). The rock contains on the average 8.78 per cent bitumen, and before the war 15,000-25,000 tons of limestone were quarried annually for treatment; but since 1920 the yearly production has ranged from 5,000 to 15,000 tons. Bitumen also occurs in the Upper Cretaceous west of St. Privat-des-Vieux. That the main deposit is of great tonnage is evinced by the fact that a well, 466 meters (1,528 feet) deep, west of St. Jean-de Maruéjols, did not pass out of the asphaltic limestone.

Developments outside Gabian area.—Outside of Gabian, also, some testing has been done. Mining for asphalt commenced in 1844 in the vicinity of Alès. Following that date the Société des Asphaltes du Centre and the Société Française des Asphaltes have continued developments by means of galleries on a bed ranging from 1.5 to 2.5 meters in thickness containing as much as 12.5 per cent bitumen.

Real prospecting activity commenced in 1903, and a score of test wells were sunk of which several reached depths as great as 450 meters. Test holes ranging from 2 to 300 meters deep, drilled in 1902 near St. Jean-de-Maruéjols, yielded showings of oil, but others, one of which was 465 meters (1,525 feet) deep, were barren. In a test for coal 262 feet deep, situated between Pont-de-Chéruy and Chavagneu, 30 liters of oil are reported to have been obtained from one cubic meter of sand. Two test wells in the Department of Hérault—one at Rabieux and the other at Nébian—were respectively 300 and 400 meters deep in 1929 and were still being drilled. A hole being sunk by Cassan and Courrière northwest of Narbonne was 210 meters (689 feet) deep and being con-

tinued. Doubtless many other holes exist which have not been reported to the writer; and, out of those that have been drilled, few have been wisely located with respect to structure and none has been of great depth outside of the Gabian area.

Production of bituminous rock.—A complete record is not at hand of the production of asphaltic limestone in the Lower Languedoc. The figures for the years 1886 to 1929 inclusive are given in Table XIX on the authority of *Statistique de l'Industrie Minière.*

TABLE XIX

PRODUCTION OF ASPHALTIC LIMESTONE IN LANGUEDOC IN METRIC TONS

Year	*Production of Asphaltic Limestone (All from Dept. of Gard)*	*Year*	*Production of Asphaltic Limestone (All from Dept. of Gard)*
1886	5,351	1908	16,379
1887	3,733	1909	15,754
1888	3,481	1910	12,923
1889	4,322	1911	11,193
1890	4,929	1912	20,783
1891	7,874	1913	24,600
1892	8,050	1914	15,299
1893	10,496	1915	5,018
1894	12,835	1916	4,601
1895	12,380	1917	3,754
1896	9,824	1918	1,843
1897	8,248	1919	5,550
1898	10,415	1920	7,948
1899	11,971	1921	15,545
1900	9,981	1922	18,657
1901	9,311	1923	15,469
1902	11,201	1924	22,458
1903	8,532	1925	18,821
1904	9,203	1926	19,400
1905	8,312	1927	20,000
1906	10,966	1928	20,000
1907	10,388	1929	22,096
		Total (through 1929 only)	509,894

Summary.—The discovery of oil at Gabian came as a surprise to French geologists as well as to petroleum geologists the world over. France had generally been represented as a country devoid of suitable structural conditions. Yet the Gabian anticline is not the only structure in the Languedoc that is similar in attitude to oil-bearing folds elsewhere in the world. Although many of the "structures" are tightly compressed or severely broken, and although many of the objective sands lie at extreme depth and are concealed by overlying unconformities or overthrusts, suitable "structures" do exist. Petroleum geologists may

have paid little attention to them; but, as is frequently the fact in undeveloped fields, some "structures" await the bold wildcatter.

It seems remarkable that the French Government has confined its attention so largely to a small area and that it has not encouraged foreign capital and foreign skill to assist in studying and testing this favorable petroliferous province. Even though the region may not have great fields, it has been proved, like the Rhine Valley, to contain fields of commercial importance, and the end of commercial development has not been reached. In fact, better fields should be expected than indicated by the losing financial venture at Gabian.

AQUITANIAN BASIN

General description.—The basin of Aquitania comprises a large part of southwestern France, extending from the *Massif Central* to the Pyrenees Mountains, fronting on the Atlantic Ocean but connecting through a narrow belt of country with the Lower Languedoc basin which borders the Mediterranean Sea. The principal streams of Aquitania are the Gironde (formed by the Garonne and Dordogne) in the north and the Adour and Gave de Pau in the south. A vast fan of tributaries carrying with them deep gravel deposits reaches these rivers from the well watered Pyrenees. The greater part of central Aquitania consists of extensive plains.

Stratigraphy and structure.—The strata of this basin (Fig. 7) range in age from Permian to Recent. In the plains portion of the region they are fairly flat to gently folded Tertiary beds, but in the south they evince folds, overthrusts, and faults, and typical *nappe* structure doubtless exists. Unconformities are numerous. The surficial geology has been studied by many geologists, especially by Fournier, Bertrand, and Viennot, the last named of whom has presented an important contribution (129). This belt, more than 40 miles wide bordering the Pyrenees, is one of most intensely folded and complicated nature, apparently intruded in places by Triassic salt and by associated masses of similar age. As the origin of the structure is involved with that of the Pyrenees Mountains themselves, it is in part too complicated to be measured by the usual standards of American geology.

In the region west from Toulouse the Permian deposits are not exposed at any point between the mountains on the south and a line extending from Toulouse to Cahors, Perigueux, and Niort on the northeast, but Permian strata may exist at depth. The Triassic is absent from the surface in the area between the Adour and a similar line, but

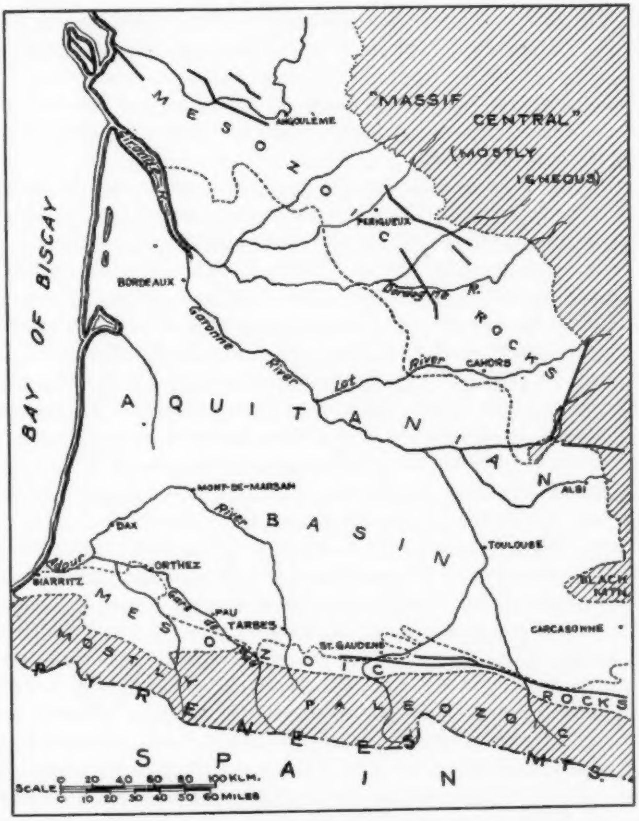

FIG. 7.—Sketch map of Aquitanian basin, after de Launay (Paleozoic and igneous areas represented by shading).

likewise may exist at depth. Certain outlying Triassic outcrops at Bastennes (north of Orthez), Department of Basses Pyrénées, and elsewhere, appear to be upthrust blocks; at any rate they are important in a proper estimate of the structure and need thorough investigation. Outliers of this type are termed "accidents" by the French geologists; and, according to Viennot (131), "the most important accidents are essentially salt domes." All types of transition between bedded salt deposits and salt domes have been reported in this basin, at Saliés de

Béarn, Carresse, Thétieu, Dax, Mimbaste, Tercis, Biarotte, and elsewhere. The highest Triassic, or Keuper, composed mainly of gypsiferous and saliferous banded clays, lies in places above the more recent sediments "found in numerous borings on the borders of the accidents (Castagnède, Gaujacq, and Tercis) where Cretaceous has been encountered beneath the Triassic."

In the pre-Pyreneean area the structural trend is either northwest-southeast or east-west. The best known anticlines are that of Audignon, 25 miles in length (midway between Orthez and Mont-de-Marsan), and the one variously called the Ste. Suzanne, Lasseube, Saliés, or Orthez anticline (122). A few miles south of the Audignon anticline and 10 miles north of Orthez lies the elevated Bastennes mass of Triassic sandstone, shale, and limestone, 15 square miles in area, cut by ophitic dikes. Although the topography suggests *Klippen* (as the Germans term occasional ancient outliers of the Alps that rest on younger strata), this block is attributed by French geologists to an upthrust mass. Wells on its outer edges are said to pass into Tertiary strata at depth.

The constitution of the western Pyrenees as being great *nappes de charriage* or overthrusts was first proved by Bertrand (8) and Termier (125) and was set forth in 1927 by Viennot (130). Throughout a largely buried Triassic area having a radius of 10 miles and lying directly south and southeast of Dax, numerous borings in search of potash have encountered great thicknesses of rock salt, some of which is highly folded and overthrust so that more recent strata lie beneath it. Salt is also mined by means of shafts in the vicinity of Bayonne; and salt and saline springs have been reported at Saliés, Sauveterre, Urt, Urcuit, Briscous, Monguerre, Bastennes, Gaujacq, Arzet, Leu, Caresse, and Donzacq (81). The brine is said to emerge from Triassic shale associated with ophitic plugs. Other ophitic intrusions exist in the vicinity of Saliés, Castagnède, Dax, St. Pandelon, and Saliés de Béarn.

Surface indications.—In the northern and central parts of the Aquitanian basin surface indications of neither petroleum nor gas are known. In the southern part, however, evidences are numerous, varied in character, and may be classified as (1) oil seepages, (2) gas seepages, (3) asphalt seepages, (4) bituminous impregnations, and (5) bituminous veins. A few of the leading examples are mentioned.

The chief example of the first named type is found at St. Boës, Basses-Pyrénées. At this place, near the north end of the Ste. Suzanne anticline, about 4 miles north of Orthez, liquid petroleum was collected by the writer from the surface of a mineral spring where the fluid emerges

from Triassic rocks. Oil is similarly reported in springs at Gaujacq and Armentières l'Echelas-siere.

Small gas seepages are reported to exist in the bed of the Gave de Pau and also at Cousters and in lowlands not far from the asphalt deposits at Bastennes. Several wells in the Pyrenees region are said to have been discontinued because of encountering dangerous gases. Bituminous impregnations in Tertiary beds are exposed at La Bastede de Boussignac nd Camarade in the Department of Ariège, at Saliés-du-Salat in the Department of Haute-Garonne and at Ligardes in the Department of Lot-et-Garonne.

In the western part of the basin, at St. Martin-de-Hinx, a bed of bitumen nearly a foot thick was exploited in 1837 by a shaft 20 meters deep and several galleries; but, at the time of the writer's visit in 1928, the area was so overgrown by forest that only a few small fragments of limestone containing tiny veinlets of grahamite could be found.

Also, just south of Orthez and not far from Ste. Suzanne, was seen a shaft, the edges of which are overgrown with bushes, near which lie numerous fragments of metamorphic limestone probably of Cretaceous age, containing veinlets and nodules of grahamite. "Asphalt" is reported to be present on this anticline throughout a length of 2 miles.

For nearly 100 years calcareous sandstone ranging from 9 to 40 per cent in bitumen was mined at Bastennes; and, according to the *Service des Mines*, its production from 1834 to 1871 was 93,400 metric tons at Bastennes on the northwest side of the *accident* and 9,000 metric tons at Gaujacq (71) on the southeast side.

We need not trust to history for evidence of the magnitude of the deposits, however, for a bed a foot or two in thickness can still be seen cropping out at the old Bastennes workings. The asphalt-impregnated beds are sands of the Burdigalian and Helvetian stages of Lower Miocene and the bituminous content may have reached its position from adjoining beds in the Triassic *accident*, for the impregnated sands are noticeably unconformable on them. Developed galleries are said to have extended more than a kilometer in length and hundreds of workmen were employed; but the work was suspended at time of the first arrival of refined oils from the United States.

Drilling done to date.—Although Table XX is a schedule of the most important test wells drilled in the basin, the prominent anticlines have not otherwise been tested.

Summary.—From the standpoint of vastness of areas, suitability of stratigraphy, and the diversity of structural conditions, the Aquitan-

TABLE XX

PRINCIPAL WELLS DRILLED IN AQUITANIAN BASIN

No.	Description (Location and Department)	Date	Depth (Meters)	Depth (Feet)	Result
1	Bastennes (several holes), Basses-Pyrénées.........				
2	Forêt des Abatilles, bordering Bay of Arcachon, Gironde	1916	40	165	Gas at high pressure burned several hours; was 31.24 per cent methane and 9 per cent nitrogen
3	Audignon, Landes..........	1925–6	859.5	2,820	Dry
4	"Dixon well" at Ste. Susanne, Landes.................	1924–5	952.5	3,124	Dry; reported "traces of asphalt"
5	Saliés-de-Bearn, Basses-Pyrénées (several holes).......				
6	Castagnède No. 1 of Soc. de Recherche de Minerais et d'Hydrocarbures, at Castagnède, Basses-Pyrénées ...			765*	Gas and showing of oil
7	Castagnède No. 2 of same company...............			110*	Gas and showing of oil
8	No. 1 of Lestage Syndicate..			150*	Dry
9	No. 2 of Lestage Syndicate..			340*	Dry
10	Dax, Landes (many wells drilled in vicinity, maximum of 3,900 feet deep in salt without reaching "substratum"...............				
11	Coutets, midway between Saliés-de-Bearn and Caresse, Basses-Pyrénées.........			480*	
12	Hippodrome well at Peyrehorade, Basses-Pyrénées...			600*	
13	No. 1 of Le Pétrole National near Castegnède.........		225	740	Showing of gas
14	No. 2 of same company.....		273	898	Dry
15	No. 3 of same company.....		297	977	Dry

*Possibly meters instead of feet.

ian basin is attractive to a pioneer in oil development. In this basin one has all objective formations from which to choose, ranging from Carboniferous to Tertiary in age, and he is faced with types of regional structure varying from the broad basin underlying the Garonne River system and the "Landes," grading through the moderate fore-front folds south of the latitude of Mont-de-Marsan and Toulouse, to the severe anticlinal types, overthrusts, and diapir structure between this latitude and the Pyrenees.

The difficulties in deciphering the subsurface geology of the region are many; among them are the intensity of folding, lack of structural

accordance at depth, and the overthrusting that exists along the Pyreneean front. Contrasted with these intensive structural factors are the flat Tertiary plains with absence of surface exposures throughout the larger part of the basin. Several types of geophysical methods, as well as the sanest geological analyses of all discovered structure, are necessary in order to make locations.

Weighing what we now know, there is every reason to suppose that oil fields will be discovered in this part of France, although their discovery must be preceded by studies as intensive as would be used in the United States.

It may be assumed that fundamental geologic conditions in the Aquitanian basin are favorable for oil, and that the failure of drilling to date is due to (1) poor location of most of the test wells, (2) inexperience of the companies with the Alpine types of structure, and (3) insufficient depth of drilling. As very few wells have attained a depth of 3,000 feet, it seems that more drilling is justifiable. However, all persons who enter the region with intent of operating should bear in mind the complex conditions and should embark on a venture only after making use of the most up-to-date geological and geophysical methods.

SAÔNE-RHÔNE VALLEY

General description.—A sedimentary basin that is structurally somewhat like those of the Rhine and the Limagne extends from the Lower Languedoc basin northward between Valence, Montelmar, and Die, along the east side of the Rhône and Saône rivers, as far as Dijon, where it touches the Paris basin across a broad Jurassic saddle 50 miles wide. An arm of the Saône-Rhône basin extends east near La-Tour-du-Pin nearly to Chambery intermediate between the Jura and the Alps.

The formations at the surface of this valley are Quaternary and late Tertiary in age, but they are evidently underlain by Mesozoic and Paleozoic beds, for Carboniferous is exposed in an east-west belt a short distance south of Lyons, connecting the St. Etienne coal basin on the west with the tip of the Jura Mountains on the east. Isolated small areas of Jurassic limestone are exposed by erosion along this valley belt for 150 miles. Tertiary beds may lie fairly flat in some parts of the valley, but they are highly folded on the Jura flanks.

Surface indications.—The most notable petroliferous indication anywhere south of the Vaux-Fevroux gas field (see Jura region) is the "Fontaine Ardente" (45) in the valley of the River Gresse, tributary to the Drac, 15 miles south of Grenoble, south of Barthéllamay, east of the

village of Pierre, and not far from the road from Mirabel to Vif. This large gas seepage, known as early as 354-430 A. D., was described by Fontennelle.[1] The gas emerges from Callovian shales of Jurassic age; and, until recently, it would explode after being allowed to accumulate for ½ hour or more. A test well was commenced in 1885, but work was stopped at a depth of 198 meters owing to gas pressure; then galleries intended to be 100 meters long are said to have been commenced, but these efforts failed because of similar difficulty. An analysis of the gas is given in Table XXI.

TABLE XXI

ANALYSES OF GAS FROM "FONTAINE ARDENTE"*

	Per Cent
Methane	98.81
Carbon dioxide	.58
Oxygen	.10
Nitrogen	.48
	99.97

*Raolt, of Academy of Sciences, Grenoble, analyst.

Other gas seepages are reported in various parts of the Rhône Valley. One seepage was ignited at Molière, not far from Die, in the Department of Drôme. Explosions are reported to have occurred, because of escaping gas during the construction of a railroad tunnel at Col de Cabre. At this writing no information is available as to wells drilled in the valley and none is known to have been sunk with the object of finding petroleum or gas.

Summary.—By studying Figure 1 the reader will understand that, as the Saône-Rhône valley lies between the petroliferous provinces of the Limagne, Languedoc, and Jura, the probability of oil and gas discoveries there may be based largely on favorable fundamental conditions as correlated between those regions. The Gabian oil field of the Languedoc, the Vaux-Fevroux gas field of the Jura, and the oil and bitumen mines of the Limagne combine with the gas seepages of the Saône-Rhône valley to render this region of some possible importance. The valley, although in part a graben, also holds many evidences of possibly favorable structure, and there is no reason to suppose that oil deposits are entirely lacking there. Like most of the petroliferous basins of France, it has been insufficiently studied by oil geologists and has been little drilled.

[1] "Observations sur les singularités de l'histoire naturelle de la France" in *Histoire de l'Academie royale des Sciences* (1699), p. 23.

ALPINE PROVINCES

General discussion.—The French Alps evince more phenomena of petroliferous nature than do most high mountains; and, although the geology may be so complicated as to offer little hope of commercial oil production, the surface indications are worth mentioning as constituting a favorable factor for accumulations in suitable subsurface structure on the west. The Alps—from Mont Blanc across the eastern, central, and southern parts of the Department of Savoie, the southeast corner of Isère, eastern and southern Hautes-Alpes, northern Alpes-Maritimes, and most of southeastern Var—are presumably eliminated from consideration because composed of igneous and metamorphic rocks. The balance of the Alpine region in the departments of Hte.-Savoie, Savoie, Hautes-Alpes, Basses-Alpes, Alpes-Maritimes, and Var may be considered as not definitely and finally eliminated, but improbable, as an area for commercial production.

From the vicinity of the "Fontaine Ardente," highly folded Mesozoic strata extend northeast, bordering the Alps to a point on the Swiss border northeast of Mont Blanc. Along this line asphaltic indications have been exploited in Urgonian limestone at Messièges, Frangy, Lovagny (where the asphalt content was 2.25 per cent), and they are also reported at Chavoroche, Bourbonges, and Challonges (Volant Perrette).

Pits sunk at Col de Châtillon, between Bonneville and Samöens, about 1855, found only inflammable gas. At Forcalquier and Manusque, in the Department of Basses-Alpes, asphalt-impregnated deposits are reported in proximity to bituminous shales and lignites. Some reports assert that Napoleon I, while crossing the Alps after his Italian campaign, warmed himself by igniting a large gas emanation at this place (45).

In addition to these comparatively well-known occurrences, gas is said to be found midway between Cluses and Samöens (59) in Hte.-Savoie, at Chevalines (124), south of Lake Annecy; and bitumen exists at two or more points at the northwest end of that lake (a kilometer or two east of Lavigny and an equal distance east of Chavand) (33); and gas has been used in some of the houses at Châtillon-sur-Cluse (59). Test wells, 250-450 meters (820-1,500 feet) deep, at Gourgeissel, in the Department of Var, found only salt water (81).

There have been, however, some semi-commercial developments of asphaltic limestone and bituminous shale, of which the production data so far as reported to the writer, are tabulated in Table XXII. An exhaustive search for production figures has not been made by the writer, and the table is therefore incomplete.

TABLE XXII

PRODUCTION OF ASPHALTIC LIMESTONE AND BITUMINOUS SHALE IN ALPINE PROVINCES, IN METRIC TONS

(According to *Statistique de l'Industrie Minière*)

	Asphaltic Limestone	*Bituminous Shale*	
Year	*Dept. of Hte.-Savoie*	*Dept. of Var*	*Dept. of Basses-Alpes*
1886	1,280	4,025	
1887	936	1,163	
1888	1,085		57
1889	1,420	5,356	
1890	1,736	2,683	98
1891	1,063		270
1892	800		719
1893	1,269		349
1894	960		273
1895	770		258
1896	1,583		469
1897	3,876		369
1898	2,661		63
1899	4,023		
1900	4,330		
1901	3,272		
1902	2,594		
1903	2,686		908
1904	2,521		
1905	1,650		
1906	2,545		
1907	2,573	10	
1908	2,317		
1909	2,303		
1910	2,918		
1911	2,923		
1912	1,174		
1913	1,663		
1914	2,876		
1915	1,347		
1916	1,647		
1917	850		
1918	217		
1919	760		
1920	1,500		
1921	3,877		
1922	5,998		
1923	4,832		
1924	5,810		
1925	6,307		
1926	7,170		
1927	7,000		
1928	7,090		
1929	6,781		
Total (through 1929 only)	122,993		

Summary.—In contrast to the views expressed for the Rhine, Limagne, Languedoc, Aquitanian, and Saône-Rhône regions, the occur-

rence of widespread gas emanations and bituminous outcrops in the Alpine departments should not be considered favorable to the development of oil or gas fields. It is possible that some small fields may be found; but the structure of this part of France is so severe and broken, without offsetting favorable fundamental conditions, that commercial deposits are not to be expected. It does not seem that geological studies in this part of France, directed toward finding oil fields, will be of value except as contributions to general geologic knowledge for application elsewhere within and outside of France.

PARIS BASIN

General description.—The great artesian basin in which Paris is situated has a Cretaceous and Tertiary area in France of 50,000 square miles (about 130,000 square kilometers) and extends from the vicinity of Meuse River on the east to Poitiers, Chinon, and Alençon on the west and from Bourges and Bar-le-Duc northwest to the English Channel, beyond which the basin continues in Great Britain. The names "Paris basin" and "London basin" are therefore practically interchangeable. The geologic province contains the greater part of the Seine, Loire, and Somme river systems and is mainly agricultural country.

Stratigraphy and structure.—The surface formations of the Paris basin range in age from Jurassic to Quaternary and are supposed to be underlain by Paleozoic rocks. The structure, in contradistinction to that of other French geologic provinces, consists of a simple succession of regionally saucer-shaped formations, each on top of the preceding one and dipping toward a common center. Broad low folds cross the basin northeast and southwest and in addition a few more important anticlines are found, of which one of the most pronounced is a continuation of the Wealdon arch of England which crosses the channel from Hastings to Boulogne. A still more pronounced anticline extends from Dieppe southeast to Neufchâtel, Beauvais, and Meaux. These two folds bring Jurassic beds to the surface in certain areas. Dollfus has described the folds of the Paris basin in some detail (37) and has shown that they maintain a northwest-southeast trend conforming to those of Brittany and are faulted in many places parallel with, and at angles to, the axes of folding.

Results of drilling.—The existence of Triassic strata underneath the surface of the basin has not been definitely proved, as nearly all of the water wells, 2,300-2,650 feet (700-800 meters) deep, were discontinued in Cretaceous or younger beds. Some wells in the vicinity of Rouen and Havre were more than 2,900 feet deep (about 900 meters) in the

Lias and yielded strong flows of brine, indicating the probability of Triassic below (45). None of the numerous water wells or other borings sunk in the Paris basin has encountered any important amounts of either petroleum or gas. A test well, drilled in 1925 on the Bray anticline at Ferrières, in the Department of Seine-Inférieure, reached a depth of 2,018 feet (611 meters) in the Middle Jurassic, with negative results.

Summary.—As the stratigraphy of the Paris basin appears potentially favorable for oil occurrence, and as most of the folds are anticlines of a mild type, the question may reasonably be asked whether this basin is not as favorable for oil or gas deposits as is any part of France. Certainly the numerous artesian water wells and the few test wells that have been drilled in search of oil have not eliminated the favorable structure from consideration, and few wells have been drilled to great depth.

On the contrary, the surface oil indications, which are so abundant in the basins of Aquitania, Languedoc, the Limagne, Rhine Valley, and the Jura Mountains, are lacking in the Paris basin. In addition to this fact little encouragement is offered by wells or outcrops within the Belgian or British borders.

By way of analogy, the Paris basin may be considered as favorable for oil or gas fields as is the vast area of the United States lying east of Mississippi River and south of the terminus of the Appalachian Mountain system, but no more so. It is strange that the structurally favorable anticlines of this basin have not been prospected by local French companies; but the lack of positive oil or gas indications would not make the basin attractive to outside capital.

BASINS OF AUTUN AND AUMANCE

Besides the important sedimentary basins there are smaller basins, a few of which have yielded traces of bituminous substances and in two of which shale has been mined. Although neither of these basins offers any chance of producing oil by drilling, they are interesting tectonically and historically. These basins are at Autun and Aumance in the upper part of the drainage basin of Loire River in the departments of Côte-d'Or, Saône-et-Loire, Nièvre, and Allier. Other small structural basins or grabens in Saône-et-Loire, Allier, and Loire have not been reported to evince petroliferous conditions but may be expected to do so.

Autun basin.—The basin of Autun, containing only about 93 square miles (241 square kilometers) and surrounded by more ancient and igneous rocks, is situated in the northeast part of Saône-et-Loire and the southwest edge of Côte-d'Or. The strata, which are Permo-Carbonifer-

ous in age, contain three zones of bituminous shale, each of which has three or more beds ranging from 1 meter to 3 meters thick. The lower zone contains the Igornay series of beds, 2.5, 1.8, and 2 meters thick, respectively, and the Lally bed, which is 4 meters thick. The middle zone has a bituminous shale band 2.5-3 meters thick and is exposed at Nuises, Dracy-St. Loup, La Cornaille, and Chambois. The upper zone contains at its top a bed of "boghead" under which are a dozen bituminous beds ranging from 0.8 to 3 meters thick. The lower of these contains a series of six beds ranging from 1.25 to 3 meters thick and is exploited at Millery, Susmoulin, Ravelon, and Margenne. The distillation of a metric ton of shale is reported to yield 23 gallons of oil, which, on fractional distillation, gives the figures stated in Table XXIII. The production in 1923 was given as 70,000 metric tons.

TABLE XXIII

RESULTS OF DISTILLATION OF AUTUN SHALES

	Yield
Gasoline	1.8 gallons
Kerosene	5.2 gallons
Heavy oil	2.6 gallons
Pitch and tar	9.1 gallons
Paraffine	6.6 pounds

Aumance basin.—The basin of Aumance (81), like that at Autun, comprises only a small area, is likewise Permo-Carboniferous in age, and, except for its structure, might be considered an arm of the Limagne graben. Bituminous shales are exploited between St. Hilaire and Buxière in western Allier. Productive beds range from 15 to 75 centimeters (6 inches to 2½ feet) thick, separated by a foot or two of barren beds, and have a total thickness ranging from 1.5 to 2.4 meters (5 to 8 feet). The bituminous beds are said to yield 5-7 per cent of oil on distillation. Table XXIV gives the available production figures in recent years, extracted from *Statistique de l'Industrie Minière*.

The Autun and Aumance basins are mentioned only to give approximate completeness to the record of oil shale production in France as a whole, and it is clear that these basins are not considered favorable to petroleum or gas occurrence.

OTHER AREAS

A few small areas containing rock of a more or less bituminous nature or traces of petroliferous material are to be found elsewhere in France. For example, strata of Permo-Carboniferous age are exposed

TABLE XXIV

PRODUCTION OF BITUMINOUS SHALE IN DEPARTMENTS OF ALLIER AND SAÔNE-ET-LOIRE, IN METRIC TONS

Year	*Production of Bituminous Shale* Dept. of Allier (Aumance)	Dept. of Saône-et-Loire (Autun)	*Distillation from Shales in Dept. of Saône-et-Loire* Crude Shale Oil	Gasoline
1886	45,444	116,763		
1887	37,000	118,274		
1888	40,777	123,409		
1889	44,503	134,725		
1890	51,053	146,539		
1891	72,817	151,933		
1892	53,425	132,183		
1893	64,009	120,462		
1894	62,390	121,394		
1895	59,199	155,173		
1896	47,207	129,781		
1897	60,327	128,399		
1898	48,472	132,473		
1899	67,427	140,734		
1900	73,573	146,070		
1901	59,261	147,876		
1902	68,198	143,861		
1903	69,699	126,743		
1904	89,034	96,244		
1905	62,907	88,582		
1906	63,206	83,826		
1907	53,988	77,830		
1908	57,305	65,823		
1909	59,374	59,355		
1910	59,720	71,063	5,423	
1911	59,467	73,565	5,467	
1912	58,428	206,518	8,079	
1913	61,070	126,704	8,657	
1914	39,537	90,315	7,315	
1915		54,400	4,026	
1916		83,004	5,891	
1917		103,414	6,879	
1918		93,138	6,979	
1919		47,985	3,234	
1920		65,913	4,800	
1921		63,040	4,203	
1922		57,739	4,900	
1923		58,173	4,525	
1924		66,843	4,900	
1925		61,950	4,570	430
1926		58,350	4,230	410
1927		85,000	?	?
1928	158	74,170	5,248	467
1929		75,913	4,733	386
1930		75,469	4,995	516
Totals	1,688,975	4,581,118	109,054	2,209

throughout an area of 300 or more square miles (700 or more square kilometers) in the Department of Manche, adjoining the Bay of the Seine. A series of bituminous "schists" is exposed at the east side of a Permian area at Litry in the edge of the Department of Calvados. At Plessis some "inflammable shales" once furnished oil on distillation, from a depth of approximately 1,150 feet (350 meters). A well sunk in 1913 beside the Aire Canal in the Department of Pas-de-Calais is reported to have had traces of light oil. None of these is worthy of consideration from the present viewpoint.

SOURCE OF OIL AND GAS

The source of petroleum in France is important, not only with respect to that country in itself, but also in connection with prospecting throughout western Europe and northern Africa. A casual inspection of the deposits at Péchelbronn and Clermont-Ferrand might give an impression that the bituminous substances originated in the Oligocene. With these exceptions the occurrences mentioned in Table XXV seem to be of older derivation, even on the basis of surficial evidence.

Notwithstanding the Mesozoic and more recent occurrences that abound throughout the country, the "mother rock" of this oil is believed

TABLE XXV

AGE OF SEDIMENTS CONTAINING OIL, GAS, OR BITUMEN

Nature of Occurrence	*Locality*	*Department*	*Age*
Asphaltic seepages	Near Clermont-Ferrand	Puy-de-Dôme	Upper Oligocene and Lower Miocene
Gas field	Vaux-Fevroux	Ain	Triassic
Asphaltic deposits	Bastennes and Gaujacq	Basses-Pyrénées	Triassic and Tertiary
Asphaltic deposits and veinlets	St. Martin-de-Hinx	Basses-Pyrénées	Triassic
Oil field	Gabian	Hérault	Triassic
Gas vents	Near Grenoble	Isère	Jurassic
Asphalt impregnations	Bellegarde valley	Ain	Eocene
Oil shales		Saône-et-Loire, Manches, Var, et cetera	Permian

by many French geologists to lie in the underlying Paleozoic—either in the Permian shales or the upper Carboniferous coal measures. The subject has been discussed at length by Barrabé (2-3) and Viennot (128-132).

The writer's investigations may not have been adequate to justify opposing any decisive evidence in the possession of a geologist who has given more time to the subject. Yet, he ventures to remark that, in the face of numerous surface indications of asphalt, oil, and gas seen in Triassic and more recent strata, he was unable to find a single seepage in Permian rocks and he knows of none in any older Paleozoic formation. To be sure, oil shales and many coals are found in Permo-Carboniferous strata; but the seepage argument should be given its full weight in evidence. Determination of the ultimate source of French petroliferous deposits is left to future investigators. It is even possible that final revelation on this subject will come from some neighboring country in which strata of identical ages and similar structural conditions are to be found.

GENERAL CONCLUSIONS

The array of figures and diversity of structural and stratigraphic conditions given in the foregoing pages is intended to concentrate, in a single place, a collection of the most authentic facts as to petroleum possibilities in France, a collection not hitherto made from a geological perspective. The writer does not pretend adequately to consider here the scientific and technical aspects of the matter. The problems involved are numerous and intricate; they can not be solved on the basis of the geology of France alone, but their solution demands the best experience that oil geology and geophysics have to offer in other countries. The development of French oil deposits, such as they are, has been retarded by the existing law on the subject, which need not be discussed here, and there is no indication of an early change in this situation. It seems probable, however, that, although France is unlikely ever to become a great oil-producing country, some paying fields may ultimately be opened within her borders.

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OCCURRENCE AND PRODUCTION OF PETROLEUM IN GERMANY[1]

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ABSTRACT

Petroleum is commercially produced in Germany in (1) the North German plain in the Hercynian foreland in connection with salt domes thrust through Tertiary and Mesozoic strata and (2) the intramontane Permian salt basin of Thuringia south of the Harz Mountains, in dolomites underlying a salt formation. The estimated production during 1931 was 1,600,000 barrels.

GENERAL OCCURRENCE

The general occurrence and commercial production of petroleum in Germany is confined to two districts: (1) the North German plain, in the Hercynian foreland, and (2) the intramontane Permian salt basin of Thuringia, south of the Harz Mountains. In the North German plain petroleum is now produced exclusively in connection with salt domes, upthrust through Tertiary and Mesozoic strata of great thickness. In the basin of Thuringia petroleum is found in Permian dolomite, underlying a salt formation.

In the sub-Alpine district south of Danube River, oil showings occur in the Flysch and Molasse zone of the Alpine front. In the Rhenish district in southwestern Germany, oil showings are found in Tertiary strata of Oligocene age.

NORTH GERMAN PLAIN

GENERAL GEOLOGY

The region of the North German plain lies on the foreland, in front of the ranges of the Permo-Carboniferous Hercynian Mountains, here represented by the Harz Mountains as their most conspicuous outcropping member. A foreland ridge, extending west-northwest and east-southeast, the Flechtinger Höhenzug, passing in the subsurface from

[1]Presented before the Petroleum Division of the American Institute of Mining and Metallurgical Engineers at the New York meeting, February, 1932. A summary of the production and drilling data, "Production of Petroleum in Germany," was published in *Petroleum Development and Technology, 1932* (Amer. Inst. Min. Met. Eng., 1932), pp. 234-37.

[2]Staatstoezicht op de Mynen.

Magdeburg in the general direction of Bremen, along Aller River, has a marked influence on general regional structure.

The present oil fields are confined to a depression, the Northwest German basin, bordered on the south by the Hercynian front, on the east by a northwest-striking buried barrier (the swell of Pompeckj) extending along Elbe River east of Hamburg, and bordered on the west by a somewhat similar barrier indicated by borings along eastern Holland. On the north it is lost in unexplored depths: the basin must extend as far as Heligoland and Heide, but should end against the buried edge of the Baltic Plateau somewhere in Denmark.

This basin is filled by a great thickness of Mesozoic and Tertiary shallow-water deposits, mostly marine, in places brackish, and in places saline formations of an aggregate thickness of 10,000 feet in the region of Hannover, increasing probably northwest. The sequence comprises Tertiary (Pliocene-Eocene, more than 3,000 feet), Upper Cretaceous (more than 3,000 feet), Lower Cretaceous, Jurassic and Triassic (also more than 3,000 feet). Many unconformities occur in this series, connected with widespread orogenic phases, notably at the base of the Tertiary, and again the lowest Cretaceous and the Upper Jurassic. These overlaps are particularly pronounced in the peripheric area of the salt domes. The Mesozoic overlies an Upper Permian salt formation of red beds, rock salt, and anhydrite, overlying bituminous dolomites and limestones. This saliferous Upper Permian unconformably overlies older Paleozoic formations (Lower Permian and Carboniferous or older).

Out of the Permian salt formation many salt plugs have been extruded and pierce the overlying sequence.

OIL FIELDS

It is exclusively in the peripheric zone of a few of these salt plugs that oil has been commercially developed, notably in the following fields, all in the general region northeast of the city of Hannover: (1) Hänigsen-Obershagen-Nienhagen, south of Celle, producing from horizons in the Upper Triassic, the Middle Jurassic, and the Lower Cretaceous; (2) Oberg, south of Peine, producing from horizons in the Middle Jurassic and Lower Cretaceous; (3) Oelheim-Eddesse, north of Peine, producing from horizons in the Upper Triassic, Lower and Middle Jurassic; and (4) Wietze, west of Celle, producing chiefly from the Lower Cretaceous.

In some of these fields production from surface seepages has been mentioned as early as 1669 (Oberg). Commercial production of importance dates only from recent time.

Wietze.—The Wietze field is the oldest; it was opened in 1859 and came to an early prime in 1882, when about 45,000 barrels were produced. Then production declined, but was revived in 1900 by the opening of a new horizon at a depth of 600-1,000 feet, from which production gradually climbed to a peak of 830,000 barrels for the year 1908. It again declined to 231,000 barrels in 1920. Since 1917 most of the oil has been produced by underground mining at a depth of 700 feet. The annual production has gradually increased (458,000 barrels in 1930 and 507,000 barrels in 1931). The main producing formation, in the Lower Cretaceous, yields a heavy, dark brown, asphaltic crude of 0.935-0.950 specific gravity. Some lighter olive-green oil of 0.885-0.920 gravity occurs exclusively in an Upper Triassic horizon of less importance.

Hänigsen-Obershagen-Nienhagen.—The most important present oil field in the plains province is that at Hänigsen-Obershagen-Neinhagen. Here also old surface seepages (tar pits) have been worked. Since 1904 development was begun by drilling, but was at first confined to a narrow zone along the west flank of the salt plug, producing from a depth of 300-600 feet. This production reached a peak of 58,000 barrels as the total for 1914. In 1920 a new zone was opened farther west in the Lower Cretaceous, yielding flowing wells of approximately 75 barrels daily. Gradually these wells reached a depth of 2,500 feet. This second development caused a new peak for the field in 1926, when a year's total was 358,300 barrels. In 1930 a new important extension was opened on the northwest, with flowing wells of as much as 3,000 barrels daily from a maximum depth of 3,100 feet. In 1930 the total production of the field was 628,300 barrels; the peak was in the month of October (83,700 barrels). The 1931 production in this field declined somewhat, reaching 542,730 barrels. The crude is heavy, dark green, non-asphaltic, of a specific gravity of 0.911-0.924.

Oberg.—The Oberg field was unimportant until 1920. Shallow wells (50-450 feet) produced a little oil from a Lower Cretaceous stratum. In 1916 drilling opened a new Middle Jurassic zone at a depth of 600-1,000 feet. Since 1920 better results were obtained in Middle Jurassic strata at a depth of 1,500-1,800 feet. Production increased from 4,800 barrels as the total for the year 1920, to 80,000 barrels in 1930. The Lower Cretaceous oil is heavy; the chief oil produced from the Middle Jurassic is a light oil of 0.850 specific gravity, containing approximately 20 per cent gasoline.

Oelheim-Eddesse.—At Oelheim-Eddesse some oil is found in Middle Jurassic and Upper Triassic horizons along the east flank of a salt plug.

In 1908-1909 production was at a peak of 12,500 barrels per year. It declined to 6,500 barrels in 1922, but was then revived by deeper drilling and reached 185,600 barrels, from a depth of 3,000 feet, for the year 1930. This field also yields a light paraffine oil containing a maximum of 30 per cent gasoline.

The combined production of the Oberg and Oelheim fields reached 353,180 barrels in 1931.

Table I gives the production of these fields of the North German plain from 1921 to 1930.

TABLE I

PRODUCTION OF FIELDS OF NORTH GERMAN PLAIN, IN BARRELS

Year	*Hänigsen-Obershagen-Nienhagen*	*Wietze-Steinförde*	*Oelheim-Oberg*	*Total*
1921	23,370	256,657	7,237	287,264
1922	71,132	234,495	6,757	314,384
1923	114,060	255,435	10,890	380,385
1924	151,725	285,337	7,680	445,140
1925	277,667	296,452	7,897	582,016
1926	358,320	331,435	25,102	714,857
1927	338,625	351,495	36,502	726,622
1928	293,917	345,795	50,355	690,067
1929	333,097	361,695	83,692	778,484
1930	628,290	458,077	185,572	1,271,939
1931	542,730	507,465	353,183	1,403,378

ORIGIN OF OIL IN PLAINS PROVINCE

Until recently, the prevailing opinion of the best informed geologists considered dark bituminous beds in the highest Triassic and lowest Jurassic (Posidonien *Schiefer*), and in the Middle Jurassic (*Polyplocus* beds), as the most probable source rocks of the oil, preserved under an efficient capping of thick Cretaceous clays. This oil would have migrated into porous reservoir beds, tilted upward by the upthrust of the salt plugs.

At present, opinion seems to change, and the possibility is considered that much or all of the oil may have migrated upward from the underlying Permian salt formation, although some Mesozoic oil may have been added to the reservoirs. The oils, though differing locally, are all chemically related, and it seems probable that they may be mere modifications evolved from the same primary crude. Oil seems to occur in *any* porous horizon that may be in contact with peripheric dislocations, causally connected with the upthrust of the salt plugs, but sand lenses which are not so situated, even though they may be intercalated

in the supposed Mesozoic source rocks themselves, contain no oil. An objection to a Permian source of the oil is that it is difficult to conceive that oil, generated in the bituminous limestones and shales below the beds of massive rock salt, could have found an outlet through this impervious *plastic* layer, which would permit no open fissures. Possibly, however, this is the very reason why so few of the salt domes seem to be productive. It has been suggested that locally the entire salt stratum has been squeezed out into the salt plugs and therefore the impervious salt capping is absent in some places, thus making productive salt domes, though many others seem barren.

DEVELOPMENT AND DRILLING METHODS

Development in the North German plain has been much retarded by lack of coöperation and a policy of secrecy of many small ownerships. At present there is a general lack of capital. In addition to first-class scientific advice, there used to be much that was quite unreliable. Most of the drilling is done by the cable-percussion system, with water flush; rotary has rarely been used so far. Testing has only seldom exceeded a depth of 3,000 feet.[1] At Wietze, since 1917, much oil has been obtained through mining methods. Galleries are driven into the oil sand, into which the oil flows by natural seepage. The heavy nature of the oil and the small gas content left in the oil sand make this method feasible without undue risk of explosions.

PROSPECTS FOR FURTHER DISCOVERIES

Only a few of the forty or more known salt domes in this basin have been developed or even tested. Many more show seepages of oil (salt domes of Hoheneggelsen, Sehnde, Hordorf, Klein-Schoppenstedt, Brunsrode, all in the triangular region between the Aller and Leine rivers). It seems very probable that more intense and better directed exploration, and deeper drilling, can develop far more important production in this region, especially if the location of test wells is carefully selected by geophysical surveying.

INTRAMONTANE SALT BASIN

A considerable embayment of the North German Permian sea encroached upon the former Hercynian highlands south of the Harz Mountains, forming the salt basin of Thuringia. Here the Permian salt beds occur at less depth than under the North German plain. Salt domes

[1]The deepest oil well (dry hole) drilled so far in this area was near Hannover: 6,187 feet. The deepest producing well is at Nienhagen: 4,376 feet.

have not been extruded, and the formations are warped in gentle anticlines and synclines, excepting some faulting. Under the rock salt, famous for its rich potash-bearing strata, occurs a sequence of variable thickness, composed of alternating dolomites and anhydrites with bituminous shales (*Stinkschiefer*) of the Middle Zechstein, and dolomites and limestones of the Lower Zechstein, with a bituminous shale (*Kupferschiefer*) at the base. This Zechstein series unconformably overlies Lower Permian (Dyassic) and the truncated folds of the Hercynian mountain structure. The bituminous shales of the Middle Zechstein (20-35 feet thick), deposited in local depressions of deeper water, are typical source rocks. The dolomites and limestones are also bituminous. The entire formation, as well as its structure, may well be compared to the oil-bearing limestones underlying the saliferous series in the Permian salt basin of West Texas and eastern New Mexico.

In this region an entirely new productive oil field was accidentally discovered. In the famous potash mine of the Volkenroda Company, in their 3,000-foot deep Menteroda workings, a blow-out of combustible gas occurred on July 2, 1930, followed by an explosion and a mysterious fire, which could only be put out by covering the shafts and cutting off all access of fresh air. It then transpired that the blow-out of gas has been followed by a very strong seepage of oil and gas, issuing from a fissure in the salt. Investigation of the strata below the salt by core-drill holes proved the existence of a widespread stratum of saturated productive dolomite, approximately 180 feet below the workings.[1]

By the middle of 1931, production amounted to about 2,800 barrels daily of a very fine light crude with about 25 per cent gasoline; the total production for 1931 is estimated at 390,000 barrels. The oil is produced through wells, core-drilled from the galleries into the dolomite. The wells are very carefully cemented and no gas is supposed to escape into the mine workings. Potash-salt mining continues undisturbed. Nearly fifty such wells had been completed in August, 1931, yielding a natural flow of 60,500 barrels in that month.[2] The wells are choked for the conservation of gas pressure.

The mine is located on a northwest-striking anticline (*Menteroder Sattel*). The limits of the productive field have not yet been established. Table II shows the production to August, 1931, inclusive.

[1]A more complete account of the discovery and the methods of exploitation is contained in a paper by W. Kauenhowen in the *Oil Weekly* of January 1, 1932.

[2]Latest detailed figures available to the writer.

TABLE II

OIL PRODUCTION AT VOLKENRODA POTASH MINE, IN BARRELS

January	11,500	May	24,200
February	9,600	June	27,000
March	11,000	July	39,200
April	16,800	August	60,600

The oil is shipped by tank cars 75 miles east to the hydrogenation plant of the I. G. Farbenindustrie at Leuna. This plant had originally been built for hydrogenation of lignite coal. The process yields 95 per cent of gasoline from the Volkenroda crude. The dangers of underground production of light oil, however, were demonstrated by a serious fire which broke out early in February, 1932, and compelled a temporary shut-down and application of concentrated carbonic acid gas for several weeks.

The effect of this important oil find will probably be an increase of German oil production by about 80 per cent. It opens very great possibilities for the entire Thuringia basin and the very similar Magdeburg basin northeast of the Harz Mountains, and even for deep drilling in the Plains area, since an important oil showing has been obtained in Zechstein dolomite as far northwest as eastern Holland, indicating similar conditions throughout.

The depth of the dolomite will be very great in the central region of the Northwest German basin (probably more than 10,000 feet), but in the southern end and on the bordering subsurface swells, both near the Holland border and along Elbe River (swell of Pompeckj), much less depth can be expected, although, on the other hand, the most favorable conditions for the deposition of bitumen in the source rocks should be found in depressions. Depressions *at the time of sedimentation*, however, need not coincide with the deepest parts of the present basin.

SUB-ALPINE PROVINCE

In the sub-Alpine province the only showing of importance so far known within Germany is at Tegernsee. The oil occurs in sandstones in overturned anticlines of the Alpine Flysch (Upper Cretaceous), thrust forward over Molasse (Tertiary). A satisfactory explanation of this showing is still lacking because of the baffling complexity of the structure. The oil is light, the specific gravity ranging from 0.731 to 0.835, and contains 20 per cent gasoline. About thirty wells have been sunk within a small area, not exceeding 125 acres, and to a depth of 3,750 feet. The total yearly production of crude had a peak of 2,280 barrels in 1909, but

was only 150 barrels in 1925. Further discoveries in this general zone, which extends eastward into Austria, are not impossible, though exploration is rendered very difficult by the complexity of the overthrust structure.

RHENISH DISTRICT OF SOUTHWESTERN GERMANY

Another area of possibilities exists in southwestern Germany in the eastern extension of the oil belt of Alsatia, in the downthrown block of the Tertiary Rhine graben between the horsts of the Vosges and the Black Forest. The western side of this area, ceded to France in 1918, contains the oil fields of Pechelbronn and a few others of less importance. The oil occurs in sand lenses in the Oligocene. At Pechelbronn they are exploited by underground mining, similar to the method described for Wietze.

That there are oil possibilities in the region east of the Rhine, in German territory, and also north of the present French frontier at Buchelberg, is indicated by oil showings in wells drilled in the Palatinate and even in Hessen. So far, however, no oil has been obtained in commercial quantity.

Table III indicates the general development of petroleum production in Germany.

TABLE III

CRUDE OIL PRODUCTION IN GERMANY, IN BARRELS

1875	5,800	1918	675,000*
1885	43,600	1919	280,000
1895	127,900	1920	264,000
1900	377,800	1921	287,000
1905	591,500	1922	314,000
1910	1,087,500	1923	381,000
1911	1,072,500	1924	445,140
1912	1,012,500	1925	583,000
1913	907,500	1926	715,000
1914	825,000	1927	727,000
1915	742,500	1928	690,000
1916	697,500	1929	779,000
1917	682,500	1930	1,272,000
		1931	1,600,000 (est.)

*Up to 1918 these figures include the Alsatian production, lost to France after 1918.

LITERATURE

The most important recent review of the oil fields of Germany in the English language has been given by W. Kauenhowen in the *Bulletin of the American Association of Petroleum Geologists*, Vol. 12, No. 5 (May, 1928), pp. 463-99; it contains a bibliography.

There have appeared several papers in Germany, notably in the weekly magazine *Petroleum*, especially the numbers 11, 15, 18, 21, 31, 40, and 43 (1931); also the previously cited paper by W. Kauenhowen in the *Oil Weekly* of January 1, 1932.

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SEARCH FOR OIL IN PARMA DISTRICT, WESTERN ITALY[1]

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ABSTRACT

The Parma district of northern Italy offers many difficult geological and geophysical problems. The writers briefly outline the stratigraphy and major structural features of the northern foothills of the Apennines, and the hidden subsurface structure of the Po Valley. Results of recent drilling have substantiated many of the geophysical interpretations.

There is a series of parallel folds trending northwest and southeast in the foothills; also in the subsurface of the plains. Secondary folding at right angles has produced closed domal structure, with Tertiary strata coming near the surface. Some dislocation with diapirism has been suspected from geophysical studies and proved by drilling.

There is no portion of the northern Apennines about which there are more controversial geological questions than the Parma district. Apart from the Pliocene system, represented for the most part by a thick complex of blue clays (Piacenziana-Plaisantian) at the base, overlain by yellow sands (Astian), concerning which there is an almost complete accord, all other formations are the object of most active controversy on the part of both Italian and foreign geologists.

The position of the formation called "Messinian," consisting in some places of an alternating series of conglomerates, sands, and marls with a fauna of *Melania*, *Melanopsis*, *Neritina*, et cetera, and in other places consisting of marls associated with thick lenses of gypsum, has been much discussed. These are estuarine or lagunal deposits referred by some to Pliocene and by others to Miocene age.

There is sufficient accord on the general reference of the thick complex of marls and sandstones "Molasse," with definite marine fossils, to the Miocene, but much divergence of opinion in the attempts to subdivide this and determine the ages of the various parts. This Miocene series has been generally ascribed in descending order to the Tortonian

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(dominantly sandy marls); to the Helvetian (dominantly sandstone); to the Langhiano (dominantly marls), but there are some who consider these divisions as facies which are chronologically equivalent.

As for the Oligocene (1),[1] the general tendency is to ascribe the sandy phases (Molasse with *Nummulites*, et cetera) to this period, but upon passing to the older formations where limestones, clay shales, and sandstones predominate, there is wide divergence of opinion as to the correct ages. The writers believe that it is wiser not to enter into this discussion, which would lead beyond the scope of the present paper.

The writers wish, however, to mention the much debated question of the age of the "Argille Scagliose." Under this name is included more or less extensive areas of complex variegated dark green clays with numerous red streaks, in many places containing broken fragments of various other rocks, chiefly sandstone and limestone, in great confusion and with no sign of stratification (2) (Fig. 1).

In these special clay areas appear greenstone masses (serpentine, diabase, eufotids, et cetera) forming sharp knobs (intrusive plugs) rising above the gently undulating clay topography (Fig. 2).

The Pliocene formations are in distinct discordance with the underlying formations, but the true relation of the "Messinian" series with the other formations is still in doubt.

The Miocene series is clearly transgressive upon the older formations and almost everywhere overlies the "Argille Scagliose."

The Oligocene strata appear in isolated spots, for the most part lying on the "Argille Scagliose," but in places included in it.

The Eocene strata also lie on the "Argille Scagliose" or are included in it.

There is a whole school of Italian geologists who maintain that the Eocene strata of the northern Apennines consist of sandstone (*macigno*) at the base, clay shales and greenstones as the middle member, and limestones at the top.

STRUCTURE

The complex tectonics of the northern Apennines are fully recognized. It is attempted here only to outline the major features, such as the double system of folds, one extending northwest and southeast, and a second at right angles.

In the zone bordering the plain of the Po, certain special structural features have been described (3), namely, the curious behavior of the

[1]Numbers in parentheses refer to Bibliography.

Fig. 1.—Typical eroded hills of "Argille Scagliose" in foreground, with more distant hills of Pliocene (Plaisantian) clays. Valley of Taro in distance.

"Argille Scagliose," which in many places has been injected into the more recent formations. This has given rise to wedge-shaped masses of "Argille Scagliose," with overflowing and spreading at the margins over younger strata,—features of diapir structure.

FIG. 2.—Hill of diabase rising from "Argille Scagliose." Notice lack of soil and numerous angular rock fragments on surface.

OIL INDICATIONS

According to the writers' observations, the indications of oil in the Emilia district are related to this special diapiric type of dislocation.

On the accompanying map are indicated the major structural trends in the Apennine foothills of the Parma region bordering the plain. Attention is directed to the correspondence of the lines of folding with the location of oil indications and springs of salt-bromine-iodine waters at the following places between the Stirone and Taro valleys: Salsomaggiore, Rio delle Ferdane, Tabiano, Miano, Medesano, S. Andrea Bagni, and between the Taro and Enza valleys at Ozzano, Neviano dei Rossi, Lesignano Bagni, Rivalta, Torre.

A curious intrusion of "Argille Scagliose" in the Piacenzian formation occurs in the extreme eastern portion of the region near Lesignano dei Bagni (Traversetolo).

A border zone of Neogene beds forms the line of low hills bordering the plain. These are chiefly Pliocene clays dipping toward the Po Valley

covered with Quaternary alluvi ı. This alluvium has been divided into an older series, generally re ˈsh and clayey, and a younger series of gravels and sands with clay leı ɜ.

The entire Valley of the Po), with the exception of the isolated hill of S. Colombiano al Lambr (Province of Milan), is covered with this alluvium, which is generally ery thick. A thick complex of Pliocene strata exists beneath this cover, and the search for the elevated portions of this Pliocene surface formed the chief object of the geophysical studies which have recently been executed by one of the writers.

The gravimetric studies made with the Eötvos torsion balance have caused the writers to modify their ideas considerably. They were able in a short time to determine the direction of buried folds which showed a trend approximately parallel with those in the hills on the south (Fig. 3).

In a well drilled at Monticelli Bagni, situated on the plain about 10 kilometers north of the foothills, salt-iodine water was encountered. It was thought that the "Argille Scagliose" had broken through the younger formations and risen to within a few tens of meters of the surface (5). This was confirmed in a well drilled several years later (Pozzo Basetti Malandriano) and also by the gravimetric survey which has brought out the subsurface topography and structure (6, 7).

Assuming for the "o" of gravity the center of the depression Gattatico S. Secondo (Province of Parma), the gravity increases with an elliptical isogammatic configuration as far as Parma with 25.10^{-4} c. g. s. (determinations of relative gravity made at Parma, July 22, 1928, with a Bamberg quadri pendulum, in the basement of Casa Gamberini, Viale Zenardelli, at an altitude of 50.90 meters above sea-level). Lat. 44°48′ gave the result $g'' = \text{cm. } 980.4619$; $g'' - \gamma_0 = -149.10^{-3}$ c. g. s. The isogam passes southeast of Parma, bordering the gravimetric closed anticline of Malandriano-Montepelato, with relative gravity maximum in respect to the "o" of Gattatico of $+105.10^{-4}$ c. g. s. Another depression lies south of Malandriano, and descends to zero near Traversetolo. Other areas of maximum relative gravity occur in the vicinity of Fonte-vivo, $+155.10^{-4}$ c. g. s., on the northwest, and Cavriago, $+90.10^{-4}$ c. g. s., on the southeast.

There is almost everywhere a compensation for the excesses or deficiencies in gravity in the surface of the plain. The anomaly of the vertical component of terrestrial magnetism is naturally of an average value corresponding with the anomaly encountered in such sedimentary areas (8).

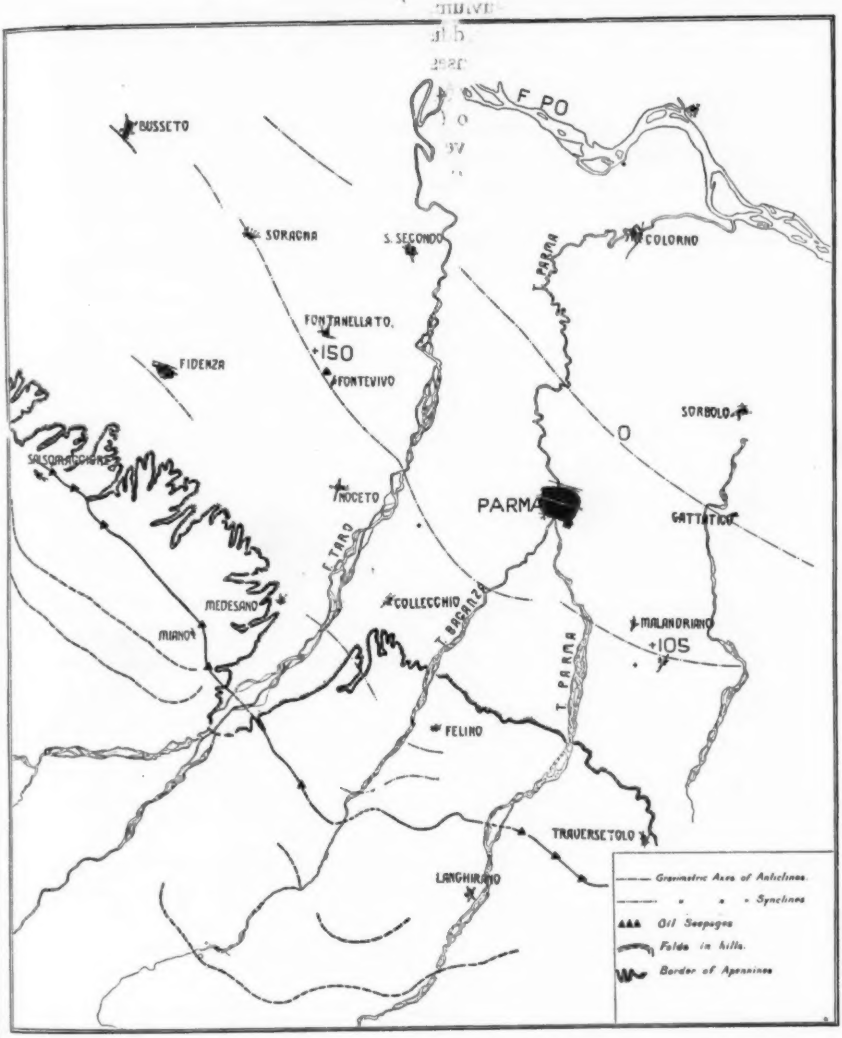

FIG. 3.—Map showing direction of buried hills approximately parallel with folds in hills on south.

Recent electrical studies by the writers have enabled them to indicate, often clearly and indisputably, that the lack of uniformity of electrical resistance in the subsoil is either in accord with the tectonic lines or with the deep mineralization of the terrain.

The map shows the perfect parallelism between the direction of the tectonic lines in the foothills and the subsurface structural lines of the plains area. It is noteworthy that these subsurface "structures" are an alternation of elevated and depressed zones which are accentuated by a secondary series of folds at right angles to the general trend.

Information obtained from drilled wells on the plain has demonstrated that the local areas of excess gravity probably correspond with elevations in the old land surface, in existence when the Pliocene was deposited. This relief caused the discordance between the Pliocene and the older formations.

Mention has already been made of the hill of S. Columbiano al Lambro which differs from other parts of the plain, because Middle Miocene strata are here overlain by marine Pliocene. In neighboring parts of the plain, the transgressive cover of Pliocene beds overlies Messinian strata with facies and fauna different from the section exposed in the hill.

It has also been mentioned that at Montepelato a test well encountered characteristic "Argille Scagliose" beneath a cover of Pliocene sandy clays near the gravimetric axis of the closed anticline. This subsurface zone of elevation of the Emilian plain corresponds almost certainly with a dislocation of diapiric type, which functioned during the Quaternary and permitted, in all probability, the rise and retention of oil and gas where conditions were favorable.

At Fontevivo, where there is another gravimetric "high," the "Argille Scagliose" has not yet been encountered, although Miocene strata have been recognized in the cores of wells drilled.

Active drilling is now being carried out on promising hidden "structures" in the plains area and the writers hope to publish further information concerning this subject.

A consideration of the oil occurrences and the geological structure of the various oil fields in Italy is now being prepared.

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REVIEWS AND NEW PUBLICATIONS

Textbook of Geology, Part I, Physical Geology. By CHESTER R. LONGWELL, ADOLPH KNOPF, and RICHARD F. FLINT. Cloth; 6 by 9; 514 pp., 341 figs. (John Wiley and Sons, Inc.) Price, $3.75 net.

Teachers and students of geology will welcome the new *Textbook of Geology, Part I, Physical Geology,* by Longwell, Knopf, and Flint, prepared and presented as an "avowed successor" to the *Textbook of Geology, Part I, Physical Geology,* by Pirsson and Schuchert. This statement is in no way derogatory to the older book, which the new publication is designed to supplant. Rather, it is a recognition that geologic knowledge and thought have advanced materially in the years that have elapsed since the Pirsson and Schuchert text was written and is an acknowledgment of the familiarity of the newer authors with the more important of these advances and of their success in presenting them in form suitable for the instruction of the elementary student.

The authors have adhered tenaciously to their avowed purpose of preparing a textbook and, furthermore, a textbook for elementary students. They seem to have recognized that a limited field can be covered by the elementary student and that intimacy of detail and multiplication of facts, that may be pertinent but that are not vital to an understanding of the fundamental principles of geology, will weaken rather than strengthen the foundation which, with the aid of this book, they strive to build.

In few places have they permitted their own enthusiasms for any particular aspect of geology to lead them from the narrow and severe path of straightforward and economical presentation of essentials into the pleasant fields of more detailed exposition of a favorite subject. One slight detour is apparent in the chapter on "Glaciers and Glaciation." Judged solely from the space allotted to these subjects, they are more important, or more difficult to explain, than any other aspect of geology, including such subjects as "Sedimentary Rocks," "Deformation of the Earth's Crust," "Origin and History of Mountains," "Land Forms," et cetera. On the whole, however, the balance of the book is excellent.

The perfect elementary textbook must be arranged in logical, easy steps. It must present its facts clearly, understandably, and interestingly. It must cover the field adequately without omission of facts that may be indispensable to the comprehension of the subject and, at the same time, must do so without superfluity of words and illustrations that may make the book unwieldy and unpleasantly expensive. Finally, it must be accurate and must strictly distinguish between fact and theory. The perfect textbook for elementary geology remains to be written but, in the opinion of the reviewer, the work under discussion has come substantially closer to it than any previous effort.

K. C. HEALD

PITTSBURGH, PENNSYLVANIA
October 1, 1932

"Die Erdöltagung der Deutschen Geologischen Gesellschaft in Hannover, 5-7 Mai, 1932. Vorträge und Verhandlungen." (The Petroleum Conference of the German Geological Society, Hanover, May 5-7, 1932. Papers and discussions). A reprint from the *Zeitschrift* of the Society, Vol. 84, Pt. 6. 512 pp., illus. (Press of Ferdinand Enke, Stuttgart.)

Recent discoveries of commercial oil deposits in Germany led the German Geological Society to devote two or three days last May to the discussion of oil geology and its problems. The papers presented on that occasion are now collected in a separate volume.

In the first paper of this collection, A. Bentz discusses the geological conditions in the four most promising petroleum provinces in Germany: the very complex subalpine basins of Bavaria and Vienna; the Upper Rhine province (the Rhine graben); the small Thuringian province; and the large salt-dome province of north Germany. This paper, which includes sketch maps and stratigraphic sections, is perhaps the most interesting in the volume to most American geologists. It brings out clearly many of the problems involved in finding oil in the four most important districts. It suggests that the two larger areas, the first and especially the fourth, are much more promising than the others.

In later papers F. Deubel, of Jena, discusses the oil possibilities of Thuringia; Alfred Kraiss discusses the gas, oil, and water of the reservoir rocks of Hanover; R. Potonie describes methods for making microscopic investigations of bitumens and the rocks enclosing them; Otto Barsch treats the problems involved in geophysical prospecting in northwest Germany; several writers describe in detail, with maps and sections, some of the new fields already discovered in north Germany; and E. Reisemann discusses gasoline manufacture in Germany.

Two of the most interesting papers deal with microscopic investigations of subsurface samples. In one of them Rudolf Wager gives the preliminary results of his examination of a few sandstone samples from three wells in the Hanover district. Whether or not the heavy minerals can be used for correlation in this area is still uncertain. W. Eichenberg, who has studied Lower Cretaceous *Foraminifera* from wells in the same area, has come to more definite conclusions. Contrary to the views of earlier German paleontologists, Eichenberg finds no difficulty in zoning the formations in question purely by micropaleontological methods.

The volume under review should prove exceptionally interesting to American oil geologists. They will be interested to note the esteem in which the *Bulletin* and the *Journal of Paleontology* seem to be held in Germany. Particularly interesting also are certain comparisons between the knowledge of regional geology in Germany and the United States. This feature comes out clearly in some of the papers under review. Owing partly, no doubt, to the longer history of geologic research in Germany, data concerning surface geology in Germany are more numerous and have been much more clearly and definitely synthesized than those in the United States. Because of the much smaller number of deep wells, however, German discussions of underground conditions often have a speculative, qualitative cast that our greater subsurface knowl-

edge sometimes enables us to avoid. If oil prospecting continues in Germany, it is likely that our present advantage in this respect will not be very long-lived.

R. D. REED

LOS ANGELES, CALIFORNIA
October 6, 1932

RECENT PUBLICATIONS

CALIFORNIA

"The Geology and Oil Resources of the Elk Hills, California," *U. S. Geol. Survey Bull. 835* (1932). (Supt. Documents, Government Printing Office, Washington, D. C.) Price, $0.60.

GENERAL

"Mining and Technology Graduates and Their Problems," by Scott Turner. *U. S. Bur. Mines Information Cir. 6649* (Supt. Documents, Washington, D. C., August, 1932). 9 pp.

"Druck- und Reproduktionsverfahren für geologische und verwandte wissenschaftliche Arbeiten" (Printing and Reproducing Methods for Geological and Related Scientific Work), by Walter Biese. *Abh. Pr. Geol. Landesanstalt, Heft 138* (1931). 46 pp., 31 pls., 21 figs.

"Theories on Origin of Petroleum," by Richard V. Hughes. *Pan-American Geologist*, Vol. 58, No. 2 (Des Moines, Iowa, September, 1932). Pp. 81-92.

World Petroleum Directory (1932-1933), published by Russell Palmer, 153 Waverly Place, New York City. First annual edition of a yearly directory containing a list of the active operating oil companies of the world; a reference work on producing, refining, marketing, et cetera. 494 pp., 8½ × 11½ inches. Cloth. Price, $10.00.

Treatise on Sedimentation, by William H. Twenhofel. The Williams and Wilkins Company (Baltimore, Maryland, 1932). 2nd ed., completely revised; new illus. xxvi + 914 pp., 121 illus. 6 × 9 inches. Cloth. Index. Price, $8.00.

GEOPHYSICS

"Études géologiques et prospections minières par les méthodes géophysiques" (Studying Geology and Prospecting for Minerals by Geophysical Methods), by P. Geoffroy and P. Charrin. *Bull. du Service de la Carte géologique de l'Algérie*, 4 Ser., Géophysique, No. 1 (1932). Press of Jules Carbonel, 11, Rue Livingstone, Alger.

GERMANY

"Die Fauna des deutschen Unterkarbons," 2 Teil (Fauna of the German Lower Carboniferous, Part 2). "Die Brachiopoden," 2 Teil (Brachiopoda, Part 2), by Werner Paeckelmann. *Abh. Pr. Geol. Landesanstalt, Heft 136* (1931). 440 pp., 41 pls., 14 figs.

"Stratigraphie der Weserkette (Oberer Dogger und Malm unter besonderer Berücksichtigung des Oberoxford)" (Stratigraphy of the Weser Chain-Upper Dogger and Malm under Special Consideration of the Upper Oxford), by

Walther Klüpfel. *Abh. Pr. Geol. Landesanstalt, Heft 129* (Berlin, 1931). 423 pp., 3 correlation charts.

"Die Stratigraphie des Oberen Malm im Lauchertgebiet (Schw. Alb) als Unterlage für tektonische Untersuchungen" (Stratigraphy of Upper Malm in the Lauchert Region, Schwabian Alb, as Basis for Tectonic Investigation), by Arthur Roll. *Abh. Pr. Geol. Landesanstalt, Heft 135* (1931). 164 pp., 7 pls., 22 figs.

KENTUCKY

"Oil Prospecting in Kentucky by Resistivity Methods," by J. H. Swartz. *U. S. Bur. Mines Tech. Paper 521* (Supt. Documents, Washington, D. C., 1932). 23 pp., 16 illus. Price, $0.05.

MINNESOTA

"The Geology and Water Resources of Northwestern Minnesota," by Ira S. Allison. *Minnesota Geol. Survey Bull. 22* (Minneapolis, 1932). Price, $1.00.

NEW YORK AND PENNSYLVANIA

"Geology of New York and Northern Pennsylvania," by Paul D. Torrey. *Amer. Petr. Inst., Div. Production.* 31,000 words, 9 illus. Mimeographed. May be purchased from Division secretary C. A. Young, 1508 Kirby Building, Dallas, Texas. Price, if sufficient orders received, $0.50.

TEXAS

"Underground Water Resources of Atascosa and Frio Counties, Texas," by John T. Lonsdale. *U. S. Geol. Survey Rept. of Investigation* in coöperation with the *Texas State Board of Water Engineers* and the *Eng. Exper. Sta., A. and M. College of Texas.* Manuscript on file for inspection at State Board of Water Engineers, Austin; Agricultural and Mechanical College, College Station; Chamber of Commerce, Pearsall, Texas; and U. S. Geological Survey, Washington, D. C. Mimeographed summary in 9 pp. and 2 maps issued as *U. S. Geol. Survey Press Memo* (October 13, 1932).

"Ground-Water Resources of the Houston-Galveston Area, Texas," by W. N. White, Penn Livingston, and S. F. Turner, *U. S. Geol. Survey Press Memo* (October 17, 1932). 16 pp., mimeographed illustrated summary of incomplete report in coöperation with the *Texas State Board of Water Engineers.*

VENEZUELA

"Larger Foraminifera from Central Falcon (Venezuela)," by Nettie E. Gorter and I. M. Van Der Vlerk. *Leidsche Geol. Mededeelingen* (Leyden Holland), Deel 4, Aflevering 2 (1932), pp. 94-122, 2 charts, 7 pls.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 16, NO. 11 (NOVEMBER, 1932), PP. 1164-1165

THE ASSOCIATION ROUND TABLE

HOUSTON MEETING, MARCH 23-25, 1933

At the invitation of the Houston Geological Society the executive committee has selected Houston for the eighteenth annual meeting of the Association. The ninth annual meeting was held in Houston in 1924. Located in Texas, the state in which nearly one-third of the members reside who live in the United States, Houston is conveniently accessible to a large majority of our geologists and engineers. Being in the Mid-Continent region, it is equally well situated for members coming from the Atlantic and the Pacific states. It is also convenient for the attendance of foreign members, particularly those in Central and South America.

Special railroad rates will be offered as usual.

Pending the appointment of the program and other convention committees, members who expect to write papers for presentation at Houston should confer with the local and regional editors about subject matter and should notify the Association editor, R. D. Reed, 929 South Broadway, Los Angeles, California, and Association headquarters, Box 1852, Tulsa, Oklahoma, so that the technical program may be properly prepared.

The officers of the Houston Geological Society are as follows.

President: John M. Vetter, Rio Bravo Oil Company

Vice-president: Sidney A. Judson, Texas Gulf Producing Company

Secretary-treasurer: John C. Miller, The Texas Company

ASSOCIATION COMMITTEES

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William B. Heroy, *secretary*, Sinclair Exploration Company, New York, N. Y.
Lovic P. Garrett, Gulf Production Company, Houston, Texas
Robert J. Riggs, Indian Ter. Illum. Oil Company, Bartlesville, Oklahoma
R. D. Reed, The Texas Company, Los Angeles, California

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C. V. Millikan (1935)
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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 16, NO. 11 (NOVEMBER, 1932), PP. 1166-1170

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

EMPLOYMENT

The Association maintains an employment service at headquarters under the supervision of the business manager.

This service is available to members and associates who desire new positions and to companies and those who desire Association members and associates as employees. All requests and information are handled judiciously and gratuitously.

To make this service of maximum value, all members and associates in the Association are requested to coöperate by notifying the business manager of openings available.

F. M. VAN TUYL and T. S. LOVERING were speakers at the regular luncheon meeting of the Rocky Mountain Association of Petroleum Geologists on September 19. Subject for discussion was "The Physiographic History of the Front Range."

EMIL OTT, geologist in West Texas for the past several years, has recently returned from a trip to his native Switzerland. He presented and interpreted a new geological wall map of that country in an address before the West Texas Geological Society at San Angelo, September 21.

M. C. LUCKY, formerly with the Houston Oil Company, is now doing independent work in the Gulf Coast region.

ROY HOLLOMAN, consulting geologist of Denver, Colorado, left in September for two months' geological work in the state of Washington. C. T. LUPTON, also of Denver, is associated with him in the investigation.

W. W. RUSK, geologist, formerly with the Producers and Refiners Corporation, Tulsa, Oklahoma, is now chief engineer and geologist for the Amarillo Oil Company. His address is 2207 Hayden Street, Amarillo, Texas.

JAMES R. DAY has accepted a fellowship in geology at the Texas Agricultural and Mechanical College and is now there working on his Master's degree.

M. MILSTEIN has left Leningrad, Russia, for Mexico. His address is Sta. M. Pacheco, Calle Iturbide 20, Mexico, D. F.

WALTER S. OLSON, for the past six years associated with the Gulf Oil Companies, in Texas, Colombia, South America, and in the Dutch East Indies, left in October for the Philippine Islands to take charge of the development of a gold mining property in the Mountain Province district near Baguio.

LUIS E. KEMNITZER, who recently returned from Germany, may be addressed at 1201 East California Street, Pasadena, California.

C. MAYNARD BOOS is studying for a Ph. D. degree at the University of Wisconsin after spending the summer with Mrs. Boos collecting and mapping the granites of the Front Range of the Colorado Rockies. Mrs. Boos is continuing her research on the heavy minerals of the granites at the same university.

FRANK A. MOSS, formerly geologist in charge of geophysical work for the Western Gulf Oil Company, recently completed six months' mining geological work in Western Australia, and is now in charge of geological work in Australia for Oil Search, Limited. At present he is investigating the oil possibilities of Queensland.

U. S. GRANT, head of the department of geology at Northwestern University, died after a short illness on September 21. His age was sixty-five years.

The Houston Geological Society elected the following officers on October 7: president, JOHN M. VETTER, Rio Bravo Oil Company, Houston; vice-president, SIDNEY A. JUDSON, Texas Gulf Producing Company, Houston; secretary-treasurer, JOHN C. MILLER, The Texas Company, Houston, Texas. The nominating committee was composed of JOHN S. IVY, GEORGE SAWTELLE, and E. E. ROSAIRE.

ALBERT D. MILLER, formerly with the Atlantic Oil Producing Company in Dallas, Texas, has accepted the position of paleontologist and analyst for the minerals division of the Louisiana Conservation Commission with headquarters in Shreveport.

KENNETH B. NOWELS, chief petroleum engineer for Forest Oil Corporation, Bradford, Pennsylvania, has a paper entitled "The Mechanics of Water Movement in Natural and Artificial Flooding of Oil Sands" in the October 3 issue of *The Oil Weekly*.

The program of the Fall Meeting of the Petroleum Division of the American Institute of Mining and Metallurgical Engineers, at Ponca City, Oklahoma, September 30 and October 1, 1932, included the following papers:

"The Place of Government, State and Federal, in Rationalizing Mineral Production," by C. K. Leith

"A Rational Program for the Oil Industry," by W. S. Farish

"Recoverable Oil and Gas Content of Land as Suitable Standard of Each Owner's Rights," by E. H. Griswold

"Reservoir Energy; Its Source, Ownership, and Utilization," by J. B. Umpleby

"Limitation of Production of Oil to Market Demand," by Robert E. Hardwicke

"Appraisal of Various Methods of Proration," by David Donoghue

"Selection and Use of Screened Pipe," by Clifford S. Wilson

"Natural and Artificial Methods of Water-Flooding," by K. B. Nowels

"The Calculation of Pressure Drops in Flowing Wells," by T. V. Moore and R. J. Schilthuis

"Gas Column Apparatus for Measurement of Bottom-Hole Pressures," by Stanley Gill

"Subsurface Pressures in Oil Wells and Their Field of Application," by D. G. Hawthorn

The Midland Geological Luncheon Club, on October 7, at Midland, Texas, elected officers as follows: president, C. D. Vertrees, Continental Oil Company; vice-president, A. P. Loscamp, Barnsdall Oil Company; secretary-treasurer, C. A. Mix, The California Company, Box 1473, Midland, Texas. The club now has an active membership list of 24.

WILLIAM M. BARRET, INC., Shreveport, Louisiana, has issued a 14-page illustrated pamphlet entitled, "Mapping Geologic Structure with the Magnetometer."

W. W. ATWOOD and KIRTLEY F. MATHER are authors of an illustrated volume of 176 pages on the San Juan Mountains of Colorado, published as U. S. Geological Survey Professional Paper 166, which may be obtained from the Government Printing Office, Washington, D. C., for $1.75.

C. K. LEITH, of the University of Wisconsin, spoke before the Tulsa Geological Society, October 1, 1932, on the subject, "The Changing Material Situation."

EUGENE STEBINGER, with the Standard Oil Company of New Jersey in Argentina, has moved his operating headquarters from Buenos Aires to Salta.

THEODORE E. SWIGART, chief production engineer of the Shell Oil Company of California, has been in The Hague in consultation with officials of the parent company.

The Shreveport Geological Society has elected the following officers: president, GEORGE W. SCHNEIDER, The Texas Company; vice-president, SIDNEY E. MIX, Gulf Refining Company; secretary-treasurer, D. N. JOLLY, consulting geologist, Shreveport, Louisiana.

H. W. C. PROMMEL, consulting geologist, 731 South Downing Street, Denver, Colorado, is vice-president and general manager of the Prommel Mining Company, and is engaged in gold placer mining on South Boulder Creek, Gilpin County, Colorado.

E. DEGOLYER, of New York City, president of the Geophysical Research Corporation, has resigned the chairmanship of the board of directors of the Amerada Corporation.

HENRY A. LEY is with the Rio Oil Corporation, 706 Fort Worth National Bank Building, Fort Worth, Texas.

The North Texas Geological Society has elected the following officers: president, VIRGIL PETTIGREW, Humble Oil and Refining Company; vice-pres-

ident, PAUL S. OLES, 505 Hamilton Building; secretary-treasurer, VERNON E. AUTRY, Humble Oil and Refining Company, Wichita Falls, Texas.

LEONARD C. THOMAS has accepted a research appointment at the University of Iowa for the forthcoming academic year.

L. R. LAUDON presented a paper, "The Stratigraphy of the Mississippian of Iowa and Northeast Missouri," at the Tulsa Geological Society meeting, October 17. J. C. ROSS presented "A Discussion of the Confusion of the Boundaries in the Lower Enid of Central Oklahoma."

L. B. SNIDER is situated at 319 Parland Place, San Antonio, Texas.

STEPHEN H. ROOK, recently micropaleontologist with the Gulf Refining Company of Louisiana at Shreveport, may be addressed at his home, 226 Del Mar Road, Montrose, California.

JOHN E. REA has an assay and engineering office in Hot Springs, New Mexico.

WILL F. EARL is working for the Mid-Kansas Oil and Gas Company of Tulsa, Oklahoma.

F. O. MARTIN has a consulting office in geology and engineering at 2038 Pine Street, South Pasadena, California.

H. H. BRADFIELD is taking special work in micropaleontology at Indiana University, Bloomington, Indiana.

EDWARD R. WOOLFOLK, formerly with the Empire Gas and Fuel Company, is at 502 C Street, N. W., Ardmore, Oklahoma.

H. B. FIELDS, formerly on the geological staff of The Texas Company, may be addressed at Box 73, Marion, North Dakota.

W. R. CALVERT is president of the Great Eastern Natural Gas Company, Inc., and of the Pennsylvania Natural Gas Company, at 73 Main Street, Wellsboro, Pennsylvania.

CHARLES E. STRAUB, 724 South Holyoke, Wichita, Kansas, is engaged in consulting practice.

J. P. WOOD has moved his consulting office to 803 West Third Street, Los Angeles, California.

C. L. COOPER, formerly chief geologist of the Oklahoma Geological Survey, is at the University of Chicago this winter.

M. W. GRIMM, who has been district geologist in East Texas, Arkansas, Louisiana, Mississippi, and Alabama, for the Tidal Oil Company, has resigned and opened a consulting office at 203 Ward Building, Shreveport, Louisiana. He will continue to represent that company in a consulting capacity, however.

RICHARD R. CRANDALL, consulting geologist, Los Angeles, has a paper entitled "Resumé of Geology of Hopper Canyon District, Ventura County, California," in the October 17 issue of *The Oil Weekly*.

W. K. ESGEN, geologist for the Humble Oil and Refining Company, has been transferred from Cisco to Houston, Texas.

JOHN A. MCCUTCHIN, formerly with the American Petroleum Institute on earth temperature research in the Mid-Continent region, is now employed by the Shell Petroleum Corporation in the Seminole area, Oklahoma.

J. S. REDFIELD, formerly with the Oklahoma Geological Survey, is with the Shell Petroleum Corporation at Greenwich, Kansas.

ARTHUR WADE, of London, has a "Note on the Geology of the Ionian Islands" in the *Journal of the Institution of Petroleum Technologists* for September.

F. H. LAHEE attended the annual convention of the Pacific Section at Los Angeles. President Lahee's itinerary includes not only Los Angeles, but also San Francisco, Seattle, Calgary, Denver, Wichita, and Tulsa. On the way out, he stopped at San Antonio and talked to members of the San Antonio Section. This trip, taken largely in the interests of the Association, was made possible through the generous interest of J. Edgar Pew, vice-president of the Sun Oil Company.

W. F. BOWMAN has been appointed land man and geologist for the recently opened Houston district offices of the Tidal Oil Company.

C. MAX BAUER is head naturalist of Yellowstone National Park.

W. O. GEORGE is now on the geological staff of the Eastman Gardner Lumber Company of Laurel, Mississippi.

C. PHILIP COLLINS is now in McAlester, Oklahoma, after spending a year in Ohio. His address is 702 South Second Street.

THEODORE A. LINK has charge of design and construction of models and exhibits in geology under the auspices of the American Petroleum Institute for the International Exposition at Chicago, 1933.

PHILIP B. KING has a paper in the November *American Journal of Science*, "Limestone Reefs in the Leonard and Hess Formations of Trans-Pecos Texas."

S. F. SHAW, formerly with the Carter Oil Company, Tulsa, has moved to 301 Terrell Road, San Antonio, Texas, to resume practice as consulting engineer.

GEORGE PINKLEY is in charge of field operations for Jacob, Buzzini and Pickett, Inc., near Whisett, Texas.

As this *Bulletin* goes to press, word is received of the death of SIDNEY POWERS, on November 5, at a St. Louis hospital after an operation.